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August 1998

Systematic Collections of the Agricultural Research Service

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Miscellaneous Publication Number 1343

August 1998

Systematic Collections of the Agricultural Research Service

J.R. Lichtenfels, J.H. Kirkbride, Jr., and D.J. Chitwood, Managing Editors

Produced by the ARS Information Staff
Editor, Bob Sowers; Graphic designer, Sandy Henry; Photo editor, Anita Daniels

Abstract

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The survival of humanity and the other organisms with which we share this planet depends on a detailed knowledge of numerous plant and animal species, varieties, breeds, cultivars, or strains exploited for food or fiber. This knowledge requires well-organized collections of reference specimens, which can be stored and retrieved as sources of information. Many such collections are included in the systematic collections of the Agricultural Research Service (ARS), U.S. Department of Agriculture.

This report describes in detail 12 systematic collections under the care of various ARS laboratories. Information is provided on the purpose, history, location, size, major achievements, and associated research programs and other provided services such as loans or identification of specimens. Many other ARS scientists curate smaller, specialized collections for their own research. Computerized databases have been developed for most of the collections. Information from some of the collections is available on the World Wide Web, and specimen records of some collections can be accessed online.

The audience for this publication includes researchers, teachers, students, and administrators concerned with the study and care of plants and animals and the broad range of living organisms that affect them by affecting the agricultural environment.

Keywords: collections, fungi, germplasm, grasses, grasshoppers, herbarium, insects, legumes, nematodes, parasites, potatoes, *Rhizobium*, seeds, species identification, systematics, taxonomy

While supplies last, single copies of this publication may be obtained at no cost from the curators of the individual collections (names, phone and fax numbers, and e-mail and mailing addresses provided on the first page of each collection's section in this publication).

Copies of this publication may be purchased from the National Technical Information Service, 5285 Port Royal Rd., Springfield, VA 22161; telephone (703) 605–6000.

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Coming soon—A version of this publication will be available on the ARS Information Staff's World Wide Web home page <http://www.ars.usda.gov/is>

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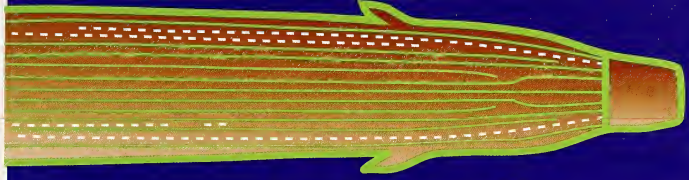

Animal Parasites

U.S. National Parasite Collection

By J. Ralph Lichtenfels, Eric P. Hoberg, and Patricia A. Pilitt

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The U.S. National Parasite Collection contains parasites of humans and animals (fig. 1). It is one of the world's largest parasite collections and is the major repository of helminth type specimens for North American parasitologists and for others who lack adequate facilities. Using their personal collections as a nucleus, Charles Wardell Stiles and Albert Hassall founded the collection in 1892.

Background

Stiles and Hassall were two parasitologists employed in the USDA Bureau of Animal Industry, which was a predecessor of the Agricultural Research Service. Stiles was an American who had studied in Europe, and Hassall was born and trained in England. As a result, some of the oldest specimens in the U.S. National Parasite Collection are from Europe and date from the middle of the 19th century.

Figure 1. Tissue-dwelling parasites in the U.S. National Parasite Collection

During its existence, the collection has had various names, and constituent collections have added additional names. The collection was known initially as the Bureau of Animal Industry (BAI) Collection, and a catalog of parasites in the collection was published (Stiles and Hassall 1894). The catalog stated that "all types of the BAI Collection will be permanently deposited in the United States National Museum . . ." (USNM). To accomplish this, Stiles proposed in 1894 that the Smithsonian Institution establish a department of zoology or helminthology and volunteered to serve as honorary curator. In March 1894, Stiles was appointed custodian of the USNM Helminthological Collection by the secretary of the Smithsonian Institution. This appointment began a tradition, still in effect, in which the curator of the National Parasite Collection also serves as a research associate of the Smithsonian Institution. The USNM Helminthological Collection has been continuously curated since 1892 by USDA scientists. If specimens ever were transferred physically to the Smithsonian, they were returned in 1936, a time that appears to coincide with the movement of the BAI Collection from Washington, DC, to new laboratory facilities in Beltsville, MD.

Over the years as bureau, agency, and division names changed, the BAI Collection became known as the Zoological Division Collection, the Animal Parasite Collection, the Beltsville Parasite Collection, and the USDA Parasite Collection. Since 1894, there have been two constituent collections, the BAI Parasite Collection and the USNM Helminthological Collection, each using blocks of catalog numbers for entries but all catalog numbers being part of a single numerical series. In 1969, Becklund proposed the overall name National Parasite Collection for these two constituent collections; he chose this name because it incorporates a broad range of organisms. Lichtenfels added "U.S." to the name to differentiate the collection from similar collections in other countries.

Although helminths are the largest group in the collection, other groups include parasitic protozoans, pentastomes, lice, mites, ticks, and other miscellaneous parasites. Many of the parasites were collected during USDA survey and eradication programs. About half of the specimens are stored in small bottles in a solution of 92 parts 70 percent ethanol, 3 parts formalin, and 5 parts glycerine. The others are mounted permanently on glass microscope slides. In

addition to Stiles and Hassall, the collection has been curated by B.H. Ransom, M.C. Hall, A. McIntosh, W.W. Becklund, and M.B. Chitwood and is currently curated by J.R. Lichtenfels, E.P. Hoberg, and P.A. Pilitt. Other USDA researchers closely associated with the collection over the years include B.G. Chitwood, E.B. Cram, G. Dikmans, J.T. Lucker, E.W. Price, and E.E. Wehr.

After the sudden death of Willard W. Becklund at age 47 in 1970, MayBelle Chitwood became curator of the National Parasite Collection until her retirement in 1973. Since 1973, the collection has been under the care of J. Ralph Lichtenfels, who has been assisted by Patricia A. Pilitt since 1977. Patricia Pilitt is the daughter of Allen McIntosh, who curated the collection from 1930 to 1962. In 1990, Eric P. Hoberg joined the staff of the Biosystematic Parasitology Laboratory (BPL) (now the Biosystematics and National Parasite Collection Unit) and now shares curatorial duties with Lichtenfels and Pilitt.

Collections and Facilities

The collection includes about 95,000 lots of specimens. An individual lot consists of one to thousands of specimens. Additions to the collection receive the next available catalog number. Specimens are not grouped taxonomically. A *Checklist of Types in the U.S. National Parasite Collection* was published in 1978. The types are listed by species within phylum or class, and an index of genera is included. Copies of the *Checklist of Types* are available from J.R. Lichtenfels, E.P. Hoberg, and P.A. Pilitt (see contributors section for addresses and phone numbers). The collection includes about 12,000 type lots, including about 4,000 holotypes.

In addition to the 95,000 cataloged lots, several large blocks of specimens have not been cataloged. These include the H.B. Ward Collection, the Hoffman-Bangham Collection of Parasites of Freshwater Fishes, and the Southeastern Cooperative Wildlife Diseases Study Collection of Parasites of White-tailed Deer. After Ward died, his collection was shipped to Beltsville along with its card file and logbook records. Although Allen McIntosh and Bill Becklund cataloged the types in the Ward Collection, most of it remains uncataloged except for Ward's records.

In 1986, the Hoffman-Bangham Collection of Parasites of Freshwater Fishes was moved to Beltsville from the Fish and Wildlife Service Fish Farming Experiment Station at Stuttgart, AR, following the retirement of Glenn L. Hoffman. It includes the personal collections of G.L. Hoffman and R.V. Bangham and a collection of Myxosporidia compiled by H.S. Davis. The Hoffman-Bangham Collection consists of more than 8,000 slides in boxes and numerous small vials in a steel chest of drawers. The specimens are indexed according to Hoffman's original records but have not been cataloged into the records of the U.S. National Parasite Collection.

The Southeastern Cooperative Wildlife Diseases Study Collection of Parasites of White-tailed Deer was moved to Beltsville in 1988 and contains 2,193 *Odocoileus virginianus* from 13 southeastern states. Each lot consists of a composite sample of all species collected from one deer and placed into a single vial. Detailed records of host and parasites are available, but the parasites are not indexed; consequently this collection has not been cataloged into the

records of the U.S. National Parasite Collection, except for specimens used in recent studies.

In addition to the large constituent collections listed above, significant personal collections of the following individuals are housed at Beltsville as part of the U.S. National Parasite Collection. Those followed by an asterisk have been cataloged fully: F.W. Douvres, J.H. Fischthal*, A.O. Foster*, A. Goldberg, E.P. Hoberg, R. Honess, R.A. Knight, D.C. Kritsky*, R.E. Kuntz*, G.R. LaRue, D.R. Lincicome, E. Linton*, G.A. MacCallum, J.H. Sandground*, L. Schultz, and H.J. Van Cleave. The uncataloged personal collections can be accessed only through original logbooks, host records, or, in some cases, by taxonomic grouping.

The collection has been housed in its present location at the Beltsville Agricultural Research Center since 1960. The facilities were improved by the addition of moveable steel shelving on rails (compactors) in 1984 and the addition of systems for fire suppression, electronic detection of intrusion, and fire surveillance in 1988. Current storage space can accommodate 10–15 years of normal accessions (about 1,000 lots per year).

Identification Service

A limited identification service is provided, with priority given to parasites of veterinary or medical importance. Emphasis is placed on the preparation of illustrated keys and manuals that permit many parasitologists to identify their own specimens.

Other services associated with the collection include a liberal and efficient loan program of specimens and an open-door policy for visiting scientists. Literature cannot be borrowed but is available to visitors. A microscope will be provided for visiting scientists, but visits must be prearranged.

Databases

Cataloged specimens of the U.S. National Parasite Collection were indexed by host and parasite scientific names in a card file until 1990, when a computerized catalog system was adopted. Because the host and parasite card indices prepared until 1990 are by genus and then species, users had to know all possible genera in which a species may have been cataloged. The pre-1990 records recently were entered into the computer database by the curators, students, and volunteers.

The new computer system provides all necessary labels, logbooks, and reports and allows logical searches for any string of characters in all fields. It is not available online.

Research

The Biosystematics and National Parasite Collection Unit develops new information on the diagnosis, identification, classification, and distribution of parasites of animals, especially those of veterinary and medical importance, using comparative morphology and biochemical and molecular genetics techniques within the context of modern phylogenetic methods for analysis. The program is centered on helminths of ruminants and food safety. Current

objectives include (1) developing classifications for subfamilies of Trichostrongylidae, including generic concepts for Ostertagiinae (fig. 2); (2) preparing identification keys to helminth parasites of domestic and wild ruminants of North America; (3) defining biodiversity of helminth fauna of bovids and cervids of Holarctic origin; (4) determining the relationship of species of *Trichinella* and developing classification of the species within the genus; (5) expanding services of the U.S. National Parasite Collection to include depositories of frozen tissue and a database on germplasm. The U.S. National Parasite Collection also supports general biodiversity research on parasitic fauna of vertebrates and historical biogeography and cospeciation analyses.

Selected Achievements

1911	Published illustrated keys to nematode parasites of ruminants
1916	Monographed nematode parasites of small mammals
1927	Monographed nematode parasites of birds
1945	Published (and later revised in 1964) *Check List of Internal and External Parasites of Domestic Animals in United States, Its Possessions, and Canada*, including data on distribution
1960	Identified exotic African red tick (*Rhipicephalus evertsi*), enabling eradication within relatively short period of a known vector of several important diseases of livestock
1961	Identified rat lungworm (*Angiostrongylus cantonensis*) from a human brain, resulting in discovery that a nematode is the causative agent of parasitic or eosinophilic meningoencephalitis in the South Pacific
1970	Published checklist of internal and external parasites of deer in North America
1971	Published descriptions and keys to many common nematode parasites of ruminants
1971	Discovered larvae of eyeworm (*Thelazia gulosa*) in face fly (*Musca autumnalis*), the first natural vector for eyeworm of cattle in eastern North America
1973	Published first manual for identification of parasites in tissue sections, including 249 figures of parasites in lesions
1975	Published illustrated keys to helminths of domestic equids, providing necessary working tool for renewed research on parasites of horses
1978	Published list of types in U.S. National Parasite Collection
1980	Published keys and new classification for Strongyloidea
1980	Published keys and new classification for Ancylostomatoidea

Figure 2. Adult male nematode showing diagnostic features

Selected Achievements (cont.)

1980	Determined larval nematode in shellfish was parasite of marine turtles
1982	Published guide to parasite collections of the world
1983	Established synlophe as most useful character for identifying species of Trichostrongyloidea (fig. 3)
1985	Described developmental stages of heartworm of dogs
1986	Discovered *Nematodirus battus* in North America (fig. 4)
1991	Published first phylogenetic analysis of Eucestoda (tapeworms) (fig. 5)
1991–93	Published identification keys to medium stomach worms (Ostertagiinae) of ruminants
1992	Developed specific DNA probes for *Trichinella* spp.
1992	Revised systematics of *Trichinella*
1992	Proposed Arctic Refugium Hypothesis to explain the evolution of host-parasite associations in the Arctic region
1994	Discovered introduction of equine strain of *Echinococcus granulosus* in North America
1994	Published identification key for large stomach worms (*Haemonchus*) of ruminants
1994	Published first phylogenetic analysis of the Trichostrongylidae
1994	Developed DNA probes for species of large stomach worms (*Haemonchus*)
1994	Developed DNA probe for fecal eggs of nematodes of cattle
1994	Published keys to genera of tapeworms of the order Tetrabothriidea

Figure 3. Ridges (synlophe) on the body surface of a nematode

Figure 4. Eggs of the nematode *Nematodirus battus*

Figure 5. Typical head of a tapeworm

1995	Discovered perivulval cuticular pores with hypodermal glands in Trichostrongyloidea
1995	Named a new genus of pathogenic lungworm in Nearctic ruminants
1995	Described a new pathogenic nematode in ratites introduced to North America
1995	Proposed Arctic Refugium Hypothesis to explain the evolution of host parasite associations in the Arctic region

U.S. National Parasite Collection

ARS Collection of Entomopathogenic Fungal Cultures

By Richard A. Humber

Location U.S. Department of Agriculture, Agricultural Research Service, U.S. Plant, Soil, and Nutrition Laboratory, Tower Road, Ithaca, NY 14853–2901

Loans Cultures are distributed to recognized institutions and scientists

Associated libraries 2,000 books, journals, and reprints; across the street from the E.A. Steinhaus collection of more than 10,000 reprints on invertebrate pathogens and pathology

Number of accessions 5,500 isolates; ca. 375 fungal species from 900 hosts

Types Few in associated herbarium facility

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Background

The Agricultural Research Service Collection of Entomopathogenic Fungi (ARSEF) was established to provide fundamental support for basic and applied research on the fungal pathogens of invertebrates. Since its inception in the early 1970's, this collection has served as a general research resource for the isolation, collection, preservation, and distribution of fungi isolated primarily as pathogens from insects, other arthropods, and nematodes. Emphasis has always been placed on acquiring and distributing strains under active study for use as potential biological control agents, but the collection is increasingly being used as a source of fungal compounds having potential uses in pest control and medicine. Basic research associated with the collection includes fungal systematics, fungal cytology, pathobiology, and methodology for fungal cryopreservation. The culture collection and its associated collection of specimens, microscope slides, and photographic images provide invaluable

support for taxonomic research on the fungal pathogens of invertebrates and the identification of these pathogens.

ARSEF was begun by Dr. Richard S. Soper as a research collection at the ARS Plant, Soil, and Water Laboratory at the University of Maine in Orono. The original prefix used to identify the collection was UMO (for its location on the University of Maine campus) and was later changed to the site-independent prefix RS (for Richard Soper). In 1985, the collection became known as ARSEF when the collection was registered with the World Data Center on Microorganisms. In 1978, the ARS Insect Pathology Research Unit (R. Soper, research leader) and its culture collection were relocated from Maine to the Cornell University campus and into facilities in the newly constructed Boyce Thompson Institute (BTI). This ARS unit, the name of which was later changed to the Plant Protection Research Unit (PPRU) in October 1985 after it merged with several small ARS units on the Cornell campus, was closely integrated with BTI's biological control program for 11 years. After occupying transitional quarters outside BTI in 1989 and 1990, the PPRU insect pathology program and the culture collection moved in November 1990 into renovated laboratory space in the U.S. Plant, Soil, and Nutrition Laboratory.

PPRU maintains and operates the ARSEF culture collection; this collection has never been owned or controlled by BTI, despite its long and close association with BTI. This culture collection is one of the largest microbial germplasm collections in USDA–ARS and is widely recognized for its active support and encouragement of global research on fungal pathogens of arthropods. There is a small herbarium associated with the collection for specimens and microscope slides. The collection acquired digital imaging capabilities for both stereo and compound microscopes in 1994 and is now accumulating an archive of digital images of entomopathogenic fungi.

Since 1977, all strains in the collection have been stored by immersion in liquid nitrogen at –196 °C, but limited cryogenic storage capacity will require many strains to eventually be shifted from cryogenic to lyophil storage. Requests for cultures are filled with either live cultures on appropriate solid or liquid media or lyophil tubes (plus instructions for fungal recovery).

Identification Service

Specimens and cultures of unidentified fungi from invertebrates can be submitted to the ARSEF curator for diagnosis. This service is an important function of the collection and is provided without charge for small numbers of specimens. Identifications and information about the status of specimens are mailed to the sender.

Databases

The ARSEF collection is managed with a customized database management application that tracks all information about accessions, storage of isolates, and requests for cultures. The software also generates forms guiding the selection and tracking of requested isolates, confirmations of cataloging information for depositions, and various reports, including fully formatted, indexed catalogs of the ARSEF collection.

Basic accession information about many ARSEF strains is available online through the Microbial Germplasm Database and accessible through the World Wide Web at <http://mgd.cordley.orst.edu/cgi-bin/mgd>. Alternatively, isolate accession data will also be available on the World Wide Web through the PPRU homepage at <http://www.ppru.cornell.edu/mycology/insect_mycology.html>.

Research

The research focus of the ARSEF collection is on the systematics, taxonomy, developmental biology, and germplasm preservation for fungal pathogens of insects, mites, spiders, nematodes, and other invertebrates. Past and current research efforts have emphasized (1) the specific, generic, and familial systematics of the Entomophthorales (Zygomycetes), particularly on resolving the complexes of *Entomophaga* species affecting lepidopteran and orthopteran hosts (fig. 6) and molecular characterization of species such as *Zoophthora radicans* (fig. 7) to track the establishment and dispersal in the field, (2) the systematics of *Metarhizium* species, (3) the clarification of the taxonomy of *Verticillium lecanii*, an important entomopathogen that appears to be a globally distributed species complex, and (4) the discovery and documentation of linkages between conidial (hyphomycete) and the ascomycetous sexual states of fungal entomopathogens such as the species of *Cordyceps* (fig. 8).

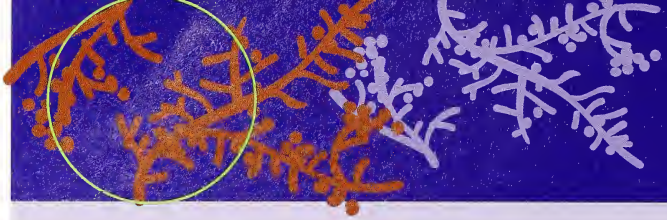
Figure 6. Grasshopper killed by a complex of *Entomophaga* species, which are distinguished by the types of spores formed, hosts, geographical ranges, and molecular and morphological characteristics

Figure 7. Leafhopper infected by *Zoophthora radicans*, an effective natural biocontrol agent. The establishment and dispersal of Serbian isolates of this species introduced against potato leafhopper in New York State was confirmed by molecular systematics techniques.

Selected Achievements

1984	Observed nuclear events in resting spores, which clarified the life history of fungi in the Entomophthorales
1986	Detected a new mode of cryptic conidiogenesis in entomophthoralean fungi
1987	Revised the taxonomy of *Metarhizium* species
1989	Definitively identified *Entomophaga maimaiga*, an important pathogen of gypsy moth larvae
1989	Prepared a new familial and generic classification of the Entomophthorales
1991	Confirmed through biochemical studies the sympatric occurrence of two closely related fungal species attacking two closely related lepidopteran hosts
1990	Confirmed that repeated fungal subculturing can negatively affect isolate pathogenicity
1995	Confirmed the usefulness of DNA techniques for tracking fungal releases in the field
1995	Confirmed that isolate pathogenicity may be affected by time in cryogenic storage

Figure 8. Cultures of this *Cordyceps* species, an ascomycete pathogen of a cicada, yield only a *Paecilomyces* conidial state. Connecting the conidial and sexual forms of insect-pathogenic fungi is essential to clarify the systematics of these fungi and to increase their utility for biological control.



U.S. National Fungus Collections

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Types 27,000

Curators

- Amy Y. Rossman, Phone: (301) 504–5364 • fax: (301) 504–5810, e-mail: <amy@nt.ars-grin.gov>, expertise in Ascomycetes, particularly the Hypocreales, *Calonectria, Nectria, Ophionectria,* plant pathogenic fungi
- David F. Farr, Phone: (301) 504–5274 • fax: (301) 504–5810, e-mail: <david@nt.ars-grin.gov>, expertise in Coelomycetes, particularly *Septoria, Stagonospora,* plant pathogenic fungi, data management
- Mary E. Palm, Phone: (301) 504–5327 • fax: (301) 504–5810, e-mail: <mary@nt.ars-grin.gov>, expertise in Deuteromycetes, particularly *Kirramyces, Plectosporium,* plant quarantine fungi
- Gary J. Samuels, Phone: (301) 504–5279 • fax: (301) 504–5810, e-mail: <gary@nt.ars-grin.gov>, expertise in Ascomycetes and their asexual states, including *Hypocrea-Trichoderma, Nectria-Fusarium,* Hypocreales, biocontrol fungi

Internet Access Telnet access <fungi.ars-grin.gov> (type "login user" and enter the password "user"); home page <http://nt.ars-grin.gov/sbmlweb/nfc/nfcframe.cfm>

The U.S. National Fungus Collections is a mycological institution that includes the world's largest herbarium of dried fungus specimens, together with technical reference literature and data files. The collection serves as a base for research and service in national and international mycology and plant pathology. Many of the technical resources and specimen data are available over the Internet through a telnet system or the World Wide Web. These resources can be accessed by contacting one of the mycologists listed above or by entering the system through the World Wide Web.

Background

Fungus collections of the Smithsonian Institution were transferred to the U.S. Department of Agriculture (USDA) in 1869 as the foundation of the Pathological Collections. Later they became the Mycological Collections and finally the U.S. National Fungus Collections, as changes in the title reflected a broadened role and status of the technical resources. In 1885, when the herbarium had fewer than 3,000 collections, F. Lamson Scribner assumed charge as the first Federal pathologist. He was followed by Franklin S. Earle in 1891, and Flora W. Patterson in 1896. Patterson organized programs and assembled a staff that notably influenced subsequent development of the U.S. National Fungus Collections. Emphasis was on the taxonomy of plant pathogens, but significant pathogens and closely related potential pathogens were also listed for nearly every fungus family.

The presence in America of the bubble disease of mushrooms, which threatened the entire industry, was first recognized in 1909 by scientists working at the U.S. National Fungus Collections. This group of scientists also was responsible for the earliest American investigations of "plaster molds" and other important pathogens of mushrooms. Before the Plant Quarantine Act was passed in 1912, Vera K. Charles and Patterson conducted pathological inspection of imported plants. Among their interceptions was the dangerous potato wart disease caused by *Synchytrium endobioticum*, which they identified for the first time in the United States on imported potatoes.

In 1917, the Plant Disease Survey was organized as a distinct project coordinated with the Pathological Collections. Cooperation between these units stimulated progress on taxonomic and host-distribution inventory of American pathogens, as documented by specimens in the U.S. National Fungus Collections. At first, nearly all research and service activities of the Pathological Collections were the personal responsibility of Patterson and Charles. In addition to Charles' studies of mushrooms, she did research on the fungal pathogens of insects. In 1941, this work culminated in the publication of a comprehensive checklist of entomogenous fungi of North America. The scientific staff working at the U.S. National Fungus Collections was increased by the appointments of Anna E. Jenkins in 1912, Edith K. Cash in 1913, and William W. Diehl in 1917. Jenkins was the foremost authority on spot-anthracnose fungi, which cause leaf and blossom disease and scab of many economically important plants. The representation of these fungi in the U.S. National Fungus Collections is the most comprehensive and taxonomically authoritative anywhere. Cash was widely recognized for her investigation of cup fungi (discomycetes), which also include major plant pathogens. Diehl's work culminated in the publication of the only modern monograph on *Balansia*, a genus of pathogens significant in causing sterility in grasses.

Patterson retired in 1923, and James R. Weir was in charge of the U.S. National Fungus Collections until 1927. While in charge of the collections, he prepared a comprehensive report on the fungi that cause diseases of the *Hevea* rubber tree. In 1927, Cornelius L. Shear collaborated with B.O. Dodge in the publication of a pioneering report on the life histories and heterothallism of red bread-mold fungi. This was the study that later brought *Neurospora* into prominence as an experimental genetic organism and opened a broad new field of genetic research.

After 1927, when John A. Stevenson succeeded Weir in charge of the collections, buildup of the herbarium and associated reference material was intensified. Stevenson had worked in Puerto Rico as a plant pathologist. He retained his interest in tropical pathology while in charge of the Mycological Collections. As a result, he collaborated extensively with tropical plant pathologists, such as F.D. Wellman, in development of the herbarium, specimen identification, preparation of geographical and host compendia, and research publications. Working relationships also were developed with outstanding national authorities, such as J.L. Lowe and G.B. Cummins, specialists in the taxonomy of wood-decay polypores and rust fungi, respectively. Ross W. Davidson was employed in 1928 to work with the U.S. National Fungus Collections. After a few years, his transfer to the Office of Forest Pathology stimulated further cooperation with that organization in the acquisition of wood-decay fungi as herbarium specimens.

In 1947, Paul L. Lentz joined the research staff associated with the U.S. National Fungus Collections. His interests in the classification and biology of wood-decay fungi resulted in a monograph on *Stereum* in 1955 and led then to the recognition and description of the fungus that causes pecky cypress. In 1958, Marie L. Farr came to the U.S. National Fungus Collections as a taxonomic specialist in the myxomycetes. She also worked extensively with black mildews and other fungi prevalent in the tropics as leaf parasites, epiphytes, and hyperparasites. Chester R. Benjamin was placed in charge of the U.S. National Fungus Collections as Stevenson's successor in 1960. Within a few years, he increased the staff by adding mycologists. John L. Cunningham, a specialist in rust taxonomy, arrived in 1965, as did Francis A. Uecker, whose specialization was in the cytology and developmental morphology of pyrenomycetes. Kent H. McKnight reestablished a program on mushroom taxonomy and ecology in 1966. The following year, Lekh R. Batra was employed to continue his diverse research projects in the classification of discomycetes, hemiascomycetes, and fungus-insect relationships. After Benjamin's departure in 1971, Lentz assumed charge of the U.S. National Fungus Collections and its associated research. Joseph F. Ammirati was employed in 1973 as an agaricologist, and he was succeeded by David F. Farr, who joined the mycology staff in 1974 to work primarily with noncultivated mushrooms and later to become the expert in computer technology.

With Paul Lentz's retirement in 1983, Amy Y. Rossman became director of the U.S. National Fungus Collections and continued the program of specimen data computerization. Her knowledge of plant pathogenic fungi in general and the Hypocreales continued the tradition of research on fungi important to U.S. agriculture. Under the guidance of Farr, two research associates—Gerald F.

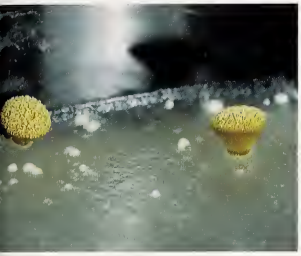

Figure 9. Sexual reproduction in *Hypocrea poronioidea* shown as ascocarps developing in culture

Bills and George P. Chamuris—provided the expertise for the relational database that resulted in the monumental account of 13,000 species of fungi reported on plants and plant products in the United States. A companion volume on the vascular plant hosts was completed by Lois A. Brako, who was assisted by Rossman and Farr.

Following the retirement of M.L. Farr and McKnight, in 1989 Gary J. Samuels was hired to develop a program on the systematics of fungi useful in the biological control of plant diseases. This work concentrated on *Hypocrea-Trichoderma* (figs. 9 and 10), with molecular expertise provided by Robert Meyer and, later, by Stephen Rehner. Tackling this extremely difficult but important group of fungi has required a team effort using morphological and molecular approaches. Samuels' strains of *Trichoderma* isolated from tropical specimens of *Hypocrea* are combined with asexual isolates to determine systematic relationships that are the basis for predicting their effectiveness. In 1994 Samuels worked with Rehner to discover a technique for producing sexuality in asexual strains of *Hypocrea* (fig. 9). Sue Mischke joined the laboratory in August 1993 and is working on the characterization of biological control fungi. Dr. Francis A. "Bud" Uecker retired on January 3, 1995. He was working on the systematics of plant pathogenic fungi in the genus *Phomopsis*, in which over 1,000 species have been described (fig. 11). Morphological and molecular approaches were used to determine whether these fungi are host specific.

Notable among the original or early acquisitions of the Pathological Collections are the exsiccati from J.B. Ellis, G.L. Rabenhorst, and H.W. Ravenel. Other early collections are from T.J. Burrill, G.W. Clinton, B.D. Halsted, E.W.D. Holway, M.E. Jones, W.A. Kellerman, and A.B. Langlois. Specimens were submitted from the U.S. Exploring Expedition under Commodore Wilkes, 1838–42, and also from the U.S. North Pacific Exploring Expedition under Commanders Ringgold and Rogers, 1853–56. The earliest American collections of fungi were those by L.D. von Schweinitz. Many of the Schweinitz collections and those by M.A. Curtis and other early American mycologists are in the U.S. National Fungus Collections. Thousands of collections also were contributed by mycologists and plant pathologists of the USDA. Some of the most extensive are from G.G. Hedgecock, Jenkins, Shear, Stevenson, and Weir.

In 1924, the valuable G. Bresadola herbarium from Italy was purchased for the U.S. National Fungus Collections, and the E.A. Rau herbarium, including

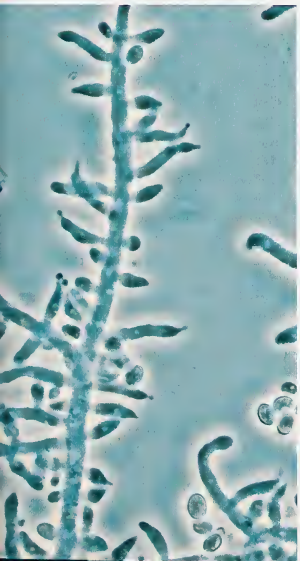

Figure 10 (left). Asexual reproduction in *Hypocrea* illustrated by the branching conidiophore of *Trichoderma*

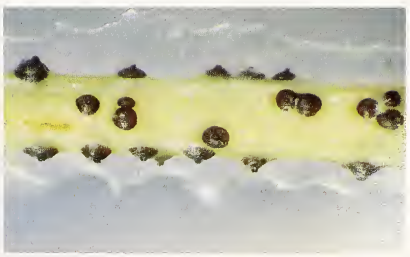

Figure 11 (right). Black pycnidia of Phomopsis developing in culture on stems of alfalfa

types, was acquired as a gift. The C.G. Lloyd herbarium was obtained in 1927. With more than 59,000 collections, it may be the largest fungus herbarium ever assembled by one person. Weir's herbarium of wood-decay fungi, acquired in 1928, also numbered many thousands of collections.

Other major acquisitions include the P.C. Standley collection from Honduras and Costa Rica; L.W. Nuttall fungi from West Virginia; remainders of the J.B. Ellis herbarium; the Sbarbaro collections from Europe; New York and Colorado collections by Shear; collections by E.A. Burt; specimens from the former Division of Cereal Crops and Disease (Bureau of Plant Industry); collections contributed by the Horticultural Crops and Diseases Division (USDA); the herbarium of R. Ciferri from the Dominican Republic; O.A. Reinking's Philippine collections; the G.L. Zundel smut herbarium; E.R. Bethel's herbarium of Colorado fungi; the W.H. Long collections of rust fungi and gasteromycetes; C.E. Chardon's herbarium of parasitic fungi from the West Indies and Central and South America; Japanese fungi from N. Hiratsuka; type specimens of P.A. Karsten's European wood-decay fungi; remainders of the Chinese National Herbarium; the J.H. Faull rust fungi; Elizabeth B. Morse's mushrooms; E.F. Guba's collections of *Pestalotia*; and the entire mycological herbaria of Goucher College, Stanford University, the Missouri Botanical Garden, and the Brooklyn Botanic Garden, including the large personal herbarium of F. Bubak and the collections of D. Griffiths and G.M. Reed.

In 1953, the fungus herbarium of the New Haven, Connecticut Forest Service Field Station was transferred to the U.S. National Fungus Collections. Another acquisition is the herbarium of the Connecticut Agricultural Experiment Station at New Haven including the smut fungi of G.P. Clinton. Another addition was the myxomycete herbarium of T.H. Macbride and G.W. Martin from the State University of Iowa, as well as myxomycetes from C.J. Alexopoulos, T. Brooks, and D. Reynolds. As a result of these acquisitions, the myxomycetes section in the U.S. National Fungus Collections is now among the most notable in the world (fig. 12). The same is true of the polypore and rust collections, as well as several other outstanding sections of the herbarium. Collections also have been received from such well-known scientists as R. Allen, J.P. Anderson, R.K. Beattie, W.W. Calkins, G.W. Carver, F.S. Earle, F.D. Fromme, F.D. Hall, J.R. Hansbrough, A.G. Johnson, C.L. Lefebrve, A. Liberta, W.H. Long, W.A. Orton, J. Rick, W.H. Snell, A.B. Seymour, E.F. Smith, F.L. Stevens, N.E. Stevens, W.T. Swingle, B.C. Tharp, S.M. Tracy, M.B. Waite, H.J. Webber, F.H. Wellman, F.A. Wolf, and many others. S. Ahmad in Pakistan and K.S. Thind in India have contributed numerous collections. Also, a policy was established by Patterson and followed by her successors for the acquisition of all sets of fungi exsiccati as they became available by purchase or exchange.

As the herbarium grew, a reference literature collection and extensive data files were developed. The library was built up principally as the personal collection of Stevenson, who donated it to the Smithsonian Institution. In 1976, an understanding between the Smithsonian Institution and the Agricultural Research Service provided for permanent maintenance by the research staff of the U.S. National Fungus Collections. Technical indexes also serve as sources of reference information in the U.S. National Fungus Collections. These include the New Taxa Index, which includes 210,000 entries; the Plant Pathogens Index,

Figure 12. Fruiting bodies of *Physarum roseum*, one of the 60,000 specimens of Myxomycetes, also known as slime molds, in the U.S. National Fungus Collections

which consists of 1,200,000 cards; a herbarium fungus and host index of 200,000 records; and an index of type specimens.

Identification Services

The specimens in the U.S. National Fungus Collections have been assembled from every major area of the world. They are used often for direct comparison with suspected pathogens. Approximately 100 loans are made each year for research throughout the world. Records for a recent, typical year show that services by the staff of the U.S. National Fungus Collections included assistance with fungal nomenclature and synonymy, fungal identification, herbarium specimen data, records of distribution and pathogenicity, information on mold prevention, information on mushroom poisoning and the eradication of mushrooms, and identification of poisonous mushrooms. Services were provided for such individuals as mycologists, plant pathologists, extension pathologists, and physicians as well as the lay public, and for institutions, including experiment stations, universities, biology publishing firms, research laboratories, government offices, museums, and hospitals.

The facilities, program, and staff of the U.S. National Fungus Collections are particularly strong in dealing expertly with mycological problems of foreign origin. The herbarium and major data files have been built up with emphasis on foreign material. Many compendia on foreign pathogens have been produced by use of these data. Support also is provided to the plant quarantine program of the USDA Animal and Plant Health Inspection Service. As international travel and commodity shipments increase, continuing development of technical information on the mycology of foreign countries is necessary for plant protection in the United States.

Databases

Databases developed at the U.S. National Fungus Collections provide access to information about fungi, primarily those associated with plants or otherwise of agricultural importance. These databases are maintained and expanded by members of the Systematic Botany and Mycology Laboratory (SBML), U.S. Department of Agriculture, Agricultural Research Service. Information about them is available through the World Wide Web site <http://nt.ars-grin.gov>. The databases can be accessed directly using <telnet fungi.ars-grin.gov> through either of two public menus. Terminal emulation must be set to VT100, the default setting at the terminal emulation prompt. Other settings for terminal emulation are listed after this prompt. To access the databases after connecting via telnet, type the words <login user> and enter a password of <user>. The USER menu will appear. To access the APHIS menu with additional databases for plant-associated fungi from throughout the world, type <login aphis> and enter the password <aphis>.

The two public menus, USER and APHIS, provide access to databases maintained at the U.S. National Fungus Collections. The databases of specimens in the U.S. National Fungus Collections, relational databases for the book entitled *Fungi on Plants and Plant Products in the United States*, and references for the identification of plant pathogenic fungi can be accessed through both menus. In addition the USER menu includes the database of books in the J.A. Stevenson Reference Library, the *Index to Saccardo's Sylloge Fungorum*, the International Mycological Institute's *Index of Fungi, 1940–1980*, and the database of C.H. Peck type specimens. The APHIS menu includes access to the database of Q37 hosts, primarily horticultural crops, *Rhododendron*, conifers, and about 200,000 unedited reports of fungi on plants from the world literature. The APHIS menu also has an option for searching all of the fungal databases.

Specimens in the U.S. National Fungus Collections. The U.S. National Fungus Collections is the repository for over 1 million fungal specimens worldwide and is the largest such collection in the world. Information associated with these specimens constitute an enormous data resource, especially about plant-associated fungi. Data from the labels of about 650,000 (65 percent) of the specimens have been entered into a database. These labels have information on the host on which the fungus was found and the locality in which the specimen was collected. Sixty percent of these specimens are from the United States and thus represent a large body of information about the fungi in this country. Data entry has been completed for the Uredinales (rusts), the Ustilaginales (smuts), the Polyporales (polypores), the Deuteromycetes (imperfect fungi), the Ascomycetes, and the C.G. Lloyd collections. Data from about 50,000 specimens and from approximately 10,000 newly accessioned specimens are entered each year.

Fungi on Plants and Plant Products in the United States. The relational databases used to produce the book *Fungi on Plants and Plant Products in the United States* are available. These databases include the reports of fungi on vascular plants and plant products according to their distribution by state. The reports are taken from over 4,000 literature sources, primarily published between 1950 and 1987, and include 13,000 fungal species on 9,000 vascular plant hosts representing 78,000 unique host-fungus combinations. The data can be searched using the scientific name of the host genus, host genus and species, fungus genus, or fungus genus and species. The common name of the host can be used to determine its scientific name. If an obsolete scientific name is entered, the database will automatically correct the name and search under the accurate scientific name. The accepted fungal names are listed with their accurate scientific names, authors, basionym, synonyms, alternate state names, geographic distribution—both worldwide and by state, host range, and relevant literature for identification. A database is maintained on the scientific and common names of the vascular plant hosts.

References on the systematics of plant pathogenic fungi. An outstanding database of current references on the systematics of plant pathogenic fungi is maintained by the mycologist for the Animal and Plant Health Inspection Service (APHIS), Dr. Mary E. Palm. She reviews the worldwide literature received at the Agricultural Research Service's SBML for important references on world distribution, taxonomy, and biology of plant pathogenic fungi and bacteria. At

present more than 16,000 references have been entered, and additional references are added periodically. Keywords for each piece of literature are derived primarily from fungus and host scientific names and country. Records can be retrieved by using author names, year of publication, or keywords. In addition data are maintained that were published in the book *Literature Guide for the Identification of Plant Pathogenic Fungi*. The database includes comments about each genus and a listing of important fungal diseases caused by species in that genus. A database of the over 5,000 books in the John A. Stevenson Reference Library is also available.

Index to Saccardo's Sylloge Fungorum. A database was developed for all the fungal names included in Saccardo's 26-volume work, *Sylloge Fungorum*, published from 1881 to 1931 and in 1972. About 117,000 fungal names are indexed, often with more than one citation.

International Mycological Institute's *Index of Fungi*, 1940–1994. A database on the International Mycological Institute's *Index of Fungi*, volumes 1–6 covering 1940–1994, is available. It can be searched by genus or species of fungus and gives the reference (volume and page) to the *Index of Fungi*.

Type specimens of Charles Horton Peck at the New York State Museum. A database of type specimens of taxa described by Charles Horton Peck is also available. This database and the specimens are maintained at the New York State Museum in Albany, NY.

Fungi on Q37 Horticultural Crops, *Rhododendron*, and Conifers. As part of a project for the Animal and Plant Health Inspection Service, information has been collected on a worldwide basis for the fungi found on some Q37 hosts or plants in growing media, primarily horticultural crops including members of the Bromeliaceae. In addition fungi found on the genus *Rhododendron* and conifers have been reported and reviewed. This information has been compiled into a database that includes information on 3,300 fungi and 89 host genera. The approach and format are identical to those used in *Fungi on Plants and Plant Products in the United States*. The database can be queried for fungi reported on a particular host and for information on the taxonomy, worldwide distribution, and host range of each fungus.

Unedited Reports from the Literature of Fungi on Plants Throughout the World. Records of the literature reporting fungi on vascular plant hosts from outside the United States are entered daily into a database. In surveying the literature for the Q37 database, all of the reports from each literature source are entered. The database includes more than 200,000 reports of fungus on plants throughout the world. Most of the data in this file have not yet been reviewed and edited by SBML personnel. Thus, there is no information about synonymy, common names, or distribution of either the fungi or the hosts.

Selected Achievements

1909	Detected first-known American case of industry-threatening bubble disease of mushrooms
1910	Discovered first-known importation of dangerous potato wart disease in America
1925	Revealed major, newly recognized group of plant pathogens as represented by citrus-scab fungus
1926	Characterized all known pathogens and diseases of *Hevea* rubber trees in South America
1927	Established fundamental significance of *Neurospora* to development of modern research in fungal genetics
1931	Developed comprehensive taxonomic key in English to all known genera of fungi
1941	Completed research on entomogenous fungi with checklist of fungal pathogens in insects in America
1950	Monographed *Balansia*, a genus of fungi causing sterility in grasses
1954	Organized definitive system for use in specialized hyphal morphology for classifying wood-decay fungi
1955	Monographed *Stereum*, an important genus of wood-decay and tree-disease fungi
1975	Documented all known fungi of Puerto Rico in the most comprehensive technical inventory available for a specific, large tropical area
1976	Monographed Myxomycetes of American Tropics
1983	Monographed the phragmosporous species of *Nectria* and related genera in the Hypocreales
1985	Monographed the species of Tubeufiaceae, many of which are parasitic on leaf fungi
1987	Published checklist of species described in *Cercospora* leaf spot fungi
1988	Completed a world list of *Phomopsis* names with notes on nomenclature, morphology, and biology, including over 1,000 species with their hosts and type specimens
1989	Published a comprehensive account of the *Fungi on Plants and Plant Products in the United States*, including 13,000 accepted fungal species on 9,000 vascular plant hosts
1991	Described the fungus causing dogwood anthracnose as the previously unknown species, *Discula destructiva*; this description served as the basis for research on this important disease

1991	Published world monograph of *Monilinia*, fungi causing brown rot of stone fruits and other diseases
1993	Produced an index to the 200,000 species of fungi as the *Index to Saccardo's Sylloge Fungorum* (available in print and electronic form)
1994	Established public access to data files of over 650,000 herbarium specimens as well as databases of fungi on vascular plants both inside and outside the United States
1995	Published book on the scientific and common names of 7,000 vascular plants in the United States, a companion volume to fungi on plants and plant products
1995	Developed checklist and account of fungi reported on *Rhododendron* throughout the world

USDA–ARS National *Rhizobium* Germplasm Collection

By Peter B. van Berkum

Location U.S. Department of Agriculture, Agricultural Research Service, Soybean and Alfalfa Research Laboratory, BARC-West, 10300 Baltimore Boulevard, Building 011, Room 19–9, Beltsville, MD 20705

Loans Cultures are distributed free of charge to recognized institutions and scientists at home and abroad.

Number of accessions 4,000

Number of additional cultures 3,000

Types The germplasm resource maintains all the type strains of the genera and species of legume symbionts and is the source for the type strains recognized by the International Subcommittee on the Taxonomy of *Agrobacterium* and *Rhizobium*.

Curator Peter B. van Berkum
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e-mail: <pberkum@asrr.arsusda.gov>

Home page <http://bldg6.arsusda.gov/pberkum/Public/sarl/welcome.html>
(URL is case sensitive; follow exact capitalization.)

Background

The Agricultural Research Service (ARS) of the U.S. Department of Agriculture (USDA) has maintained a collection of nitrogen-fixing legume symbionts for most of the 20th century. However, in the past the activities of the collection were not directly funded by ARS. The collection of strains grew in response to the requirements of the research programs during the decades prior to the 1970's. During this time, the scientists interacted with the public and provided mainly inoculants to individuals who had legitimate needs for research purposes or for the production of specific crops.

During the 1970's, an awareness of the critical importance of biological nitrogen fixation in agricultural production ensued because of the energy crisis. It was quite evident that the limitation of nitrogen in agriculture was a worldwide phenomenon and that poor nations suffered most because of rising

energy costs. The result was that it became increasingly necessary to rely on the production of leguminous crops and management of the *Rhizobium*-legume symbiosis to provide the world's population with food, raw materials, and alternative energy sources. Within this climate, the critical need for a culture collection of characterized *Rhizobium* was identified during the first three North American *Rhizobium* conferences. USDA was recognized as possessing the most comprehensive collection, and the established links with the public and private sectors were considered advantageous for technology transfer.

Because the goals of the culture collection were relevant at the international level, funding for its activities was at first provided by the Agency for International Development (USAID). This support was responsible for the establishment of the basic infrastructure in the laboratory to preserve and keep records of the accessions in the collection. One of the objectives of USAID's funding was to provide a means by which scientists of lesser developed countries could preserve their cultures when they lacked the technology for doing so in their laboratories. Ironically, LiphaTech took advantage of the objectives of the culture collection during this time to streamline its own collection, sending less commercially important accessions to USDA for preservation. The international status of the collection was further enhanced during the 1980's by its designation as a Microbiological Resource Center (MIRCEN) by the United Nations Educational and Cultural Organization (UNESCO) and the United Nations Environmental Program.

ARS, in recognition of the importance of the collection, initiated funding when USAID support ended in 1990. Although international funding from USAID ceased, the collection continues to participate in the UNESCO program, and the activities associated with the objectives of MIRCEN remain active. The program gained further recognition when it became the repository for type strains of genera and species, as well as for reference strains representing genetic diversity. The *Rhizobium* collection initiated this program in 1993 upon the request of the International Subcommittee on *Agrobacterium* and *Rhizobium*, which is a subcommittee of the International Committee on Systematic Bacteriology of the International Union of Microbiological Societies.

During the time that the collection has been funded (1975–present), the number of accessions has increased by approximately fivefold (fig. 13). The number of strains in the collection has increased over this time period because of incorporation of collections from LiphaTech, the Boyce Thompson Institute, USDA–ARS in Minnesota, the University of Sao Paulo, and Centro Internacional de Agricultura Tropical (CIAT). These collections represented significant numbers of characterized strains that could no longer be maintained or were in danger of being lost. Approximately 3,000 cultures representing the annual medic strains from the International Center for Agricultural Research in Dry Areas, the Thai soybean strains, the bean strains of CIAT, and the core collection of Nitrogen Fixation in Tropical Agricultural Legumes have been received and need to be incorporated into the ARS collection. It is estimated that over the next 5-year period the number of accessions in the Beltsville collection will double.

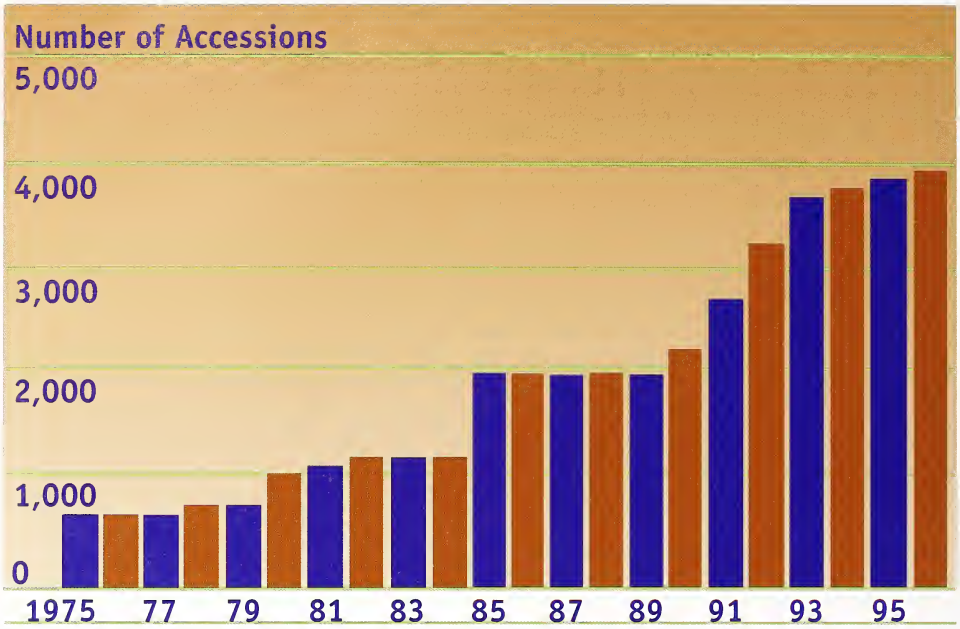

Figure 13. Number of accessions in the USDA–ARS National *Rhizobium* Germplasm Collection

Over the past quarter century, the number of cultures disbursed to fill requests has increased from approximately 200 to 800 per year (fig. 14). Although some strains are more popular than others, the number of requests for any one specific strain is less than 5 percent of the total. The higher volume has increased expenditures for postage and consumed more resources for quality control and culture preservation.

Since 1975, the accessions have been maintained as suspension cultures in 20 percent glycerol stored at –70 °C, as well as in lyophilized form. Also, a separate set is stored in lyophilized form for disbursement in response to requests for cultures. Newly acquired cultures are checked for contamination upon their receipt and are verified as legume symbionts by plant testing for nodulation on the original host of isolation. Soil samples are collected from centers of origin of legume hosts for the isolation and acquisition of additional biodiversity. Currently, the resources include four freezers maintained at –70 °C and three maintained at –20 °C, a walk-in growth room for quality control, a walk-in cold room for storage of cultures and soil samples, a laminar-flow hood, a lyophilizer, and an incubator for culturing the bacteria.

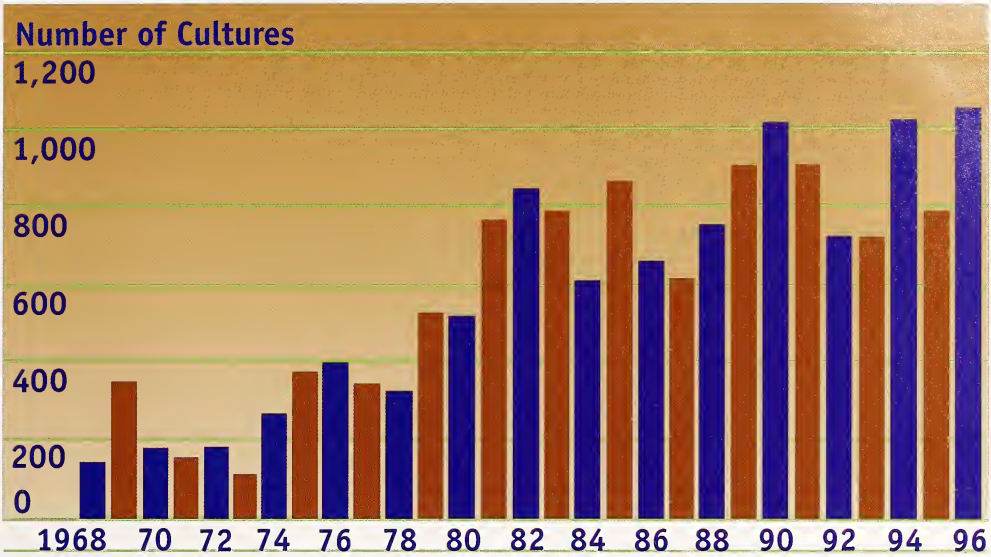

Figure 14. Number of cultures dispersed from the collection each year since 1968

The objectives of the program include the following:

1. Preserve the nitrogen-fixing symbionts of legumes with the goal of maintaining wide genetic diversity.
2. Maintain quality control of existing and new germplasm.
3. Maintain records of accessions.
4. Distribute cultures without charge.
5. Provide technical information about cultures, their preservation, and their characteristics.
6. Acquire, maintain, and distribute type strains for all of the different rhizobial taxa.
7. Train scientists under the UNESCO Fellowship in Biotechnology Program.

Database

Currently no database of the rhizobial germplasm resource is available. However, a database is being constructed. Relevant portions of holdings should eventually be available to the public through the GRIN system.

Research

The focus of the current research is on systematics of the legume symbionts for identification and classification purposes. The approach taken is predominantly molecular systematics.

Biodiversity within species is determined using protocols for the polymerase chain reaction (PCR), with primers for repeat sequences present in bacterial genomes. Repeat sequences targeted for amplification are DNA regions between repetitive extragenic palindromic (REP) sequences, enterobacterial repetitive intergenic consensus (ERIC) sequences, and BOX sequences. The amplification products are separated according to molecular size by using horizontal agarose gel electrophoresis. The gels are photographed for quantitative comparisons of the lanes according to the presence of products or their absence across lanes. This is achieved by scanning the image into a computer and by using specialized software packages. The resultant binary matrix is used to produce a dendrogram and to measure the fit of the dendrogram to the data.

DNA relatedness among strains is estimated with DNA reassociation analysis. This relies upon the double-stranded (native) nature of DNA and the property that the complementary strands dissociate at high temperature and reassociate at lower temperature. DNA homology is an attempt to answer whether the DNA of two organisms have a base sequence sufficiently similar to allow the formation of DNA heteroduplexes. DNA homology values are measurements of similarity in which the entire genome of one organism is compared with that of another. DNA homology values are used to detect similarities between closely related organisms and to conclude whether two strains belong to the same species.

Microbial phylogeny is estimated from sequencing analysis of the ribosomal genes. In particular, sequencing the 16S or small-subunit (SSU) ribosomal RNA (rRNA) gene and the 23S or large-subunit (LSU) rRNA gene. The Rhizobiaceae do not form a branch, which is distinctly different than the other genera in the alpha subdivision of the Purple Bacteria, and therefore they constitute several lineages evident as separate genera. The effort with ribosomal gene sequencing is focused on identification of the genera of accessions, preliminary estimation of speciation, and the uncovering of novel nucleotide sequences for use in strain and species identification.

Selected Achievements

Eleven scientists were supported by the USAID program during the period 1975–87. The training period was usually 12 months. These visitors were from Iraq, Spain, Thailand, Tanzania, the People's Republic of China, Mali, Egypt, Kenya, Zambia, and Pakistan.

Three visitors were accommodated who received Fulbright Scholarships and who chose to participate in the activities associated with the collection. These visitors were scientists from Ethiopia, India, and Brazil.

One trainee from Brazil who had independent support was accommodated for 24 months.

UNESCO supported one fellowship for a scientist from Spain.

The U.S. Department of Agriculture, Foreign Agricultural Service, International Cooperation and Development, Research and Exchanges Division supported two projects within the germplasm resource program under the Scientific Cooperation Program. Both projects supported scientific collaboration and germplasm exchange with the People's Republic of China.

In 1993 the International Subcommittee on *Agrobacterium* and *Rhizobium*, which is a subcommittee of the International Committee on Systematic Bacteriology of the International Union of Microbiological Societies, requested that staff of the USDA–ARS National *Rhizobium* Culture Collection maintain and distribute the type strains of the taxa of legume symbionts. The objective was to facilitate the distribution of the type strains as reference cultures and to have this function performed by an organization capable of maintaining superior quality control of these cultures.

USDA–ARS National Rhizobium Germplasm Collection

National Museum of Natural History Entomological Collection

By Douglass R. Miller, Douglas C. Ferguson, Arnold S. Menke, David A. Nickle, Robert L. Smiley, and Richard E. White

Location U.S. Department of Agriculture, Agricultural Research Service, Systematic Entomology Laboratory, BARC-West, 10300 Baltimore Boulevard, Buildings 012, 046, and 047, Beltsville, MD 20705, and National Museum of Natural History, MRC 168, Smithsonian Institution, Washington, DC 20560

Loans To recognized institutions and scientists

Associated libraries Over 6,000 volumes; 3,000 linear feet of reprints

Number of accessions 30 million specimens

Types 90,000 primary types

Curators Although Smithsonian Institution scientists have ultimate authority for the curation of the collection and hold the title of curator, U.S. Department of Agriculture scientists spend considerable effort on curatorial functions and manage large portions of the collection.
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Phone: (301) 504–5183 • fax: (301) 504–6482
e-mail: <mstoetze@sel.barc.usda.gov>

Home page <http://www.sel.barc.usda.gov>

The National Entomological Collection is one of the largest in the world. It serves as a primary repository for insects of the United States but also has large holdings of material from all parts of the world. Specimens in the collection are used as a basis for important systematic research and are a critical part of the research programs of most fields of entomology. The large holdings of agriculturally important species make this collection especially significant as a source of systematic research and for identification of insect pest groups.

Background

Entomologists outside the Washington, DC, area are frequently confused about the relationship of the U.S. Department of Agriculture's (USDA) Systematic Entomology Laboratory (SEL) and the Smithsonian Institution's National Museum of Natural History (NMNH), Department of Entomology and the function these organizations perform for the collection. This confusion results from a long history of cooperation between these distinct and separate organizations. During the early history of U.S. systematic entomology (1880's), C.V. Riley served concurrently as chief entomologist for USDA and honorary curator of insects for the Smithsonian; L.O. Howard also served in this double role. In 1925, USDA entomological taxonomists were assigned to a division of the Bureau of Entomology; this division has been maintained to the present with a few changes in name and rank. Throughout their long and productive association, USDA and Smithsonian personnel have successfully worked in concert toward the goal of developing a large and useful national collection of insects.

Although the Smithsonian's U.S. National Museum (USNM) was established in 1842, the first record of an insect collection actually stored in the museum does not appear until 1858. Because of insufficient funds in the 1860's, most of the USNM insect collection was sent to collaborating specialists with the stipulation that the material could be reclaimed at any time. By the early 1870's, the USDA was made the repository for the Smithsonian insect collection, so the Smithsonian collection was combined with the USDA collection. The USDA collection began with the acquisition of the personal collection of Townend Glover, the first chief entomologist of the USDA. From 1867 until 1881 the collection expanded and thrived through the efforts of Glover, Riley, and J.H. Comstock. In 1881, with Riley's reappointment as chief entomologist, the USDA insect collection was officially transferred to the USNM. When Riley donated his personal collection to the USNM in 1886, the holdings of insects in the USNM had reached the status of a major entomological repository. In 1969, the name of the former U.S. National Museum was officially changed to the National Museum of Natural History.

The first salaried Smithsonian entomologist was J.B. Smith, who served as assistant curator from 1885 to 1889. He was succeeded by Martin Linell, who was a museum aide from 1889 to 1897. From 1897 until 1940, the Smithsonian had two salaried positions in entomology, excluding clerical assistants. From 1940 to the present, the scientific staff expanded to 10 full-time scientists and several research associates. They are joined by the 20 full-time scientists of SEL.

Identification Service

The service responsibilities of SEL are extensive. From 1990 through 1994, the laboratory reported 89,780 identifications, including about 288,000 specimens. These identifications provide basic support for biological control projects, environmental studies, and diverse research, extension, and control activities of Federal and state agencies and other organizations in the United States and abroad. During the same period, 12,000 urgent identifications for quarantine purposes were made. These determinations are especially important, because they involve shipments that are being held at U.S. ports-of-entry pending identification of the insect or mite detected on the commodity. The laboratory scientist immediately identifies the specimens and reports the

information to personnel of the Animal and Plant Health Inspection Service, who must make a decision about the disposition or treatment of the contaminated commodity. Over the past several years the total number of identifications has decreased because the laboratory has been unable to replace retired staff and thus has lost specialists in several areas of taxonomy.

Instructions on how material should be submitted can be obtained by accessing the SEL home page <http://www.sel.barc.usda.gov> or by sending a request to Leader, Communications and Taxonomic Services Unit, Systematic Entomology Laboratory, U.S. Department of Agriculture, Agricultural Research Service, 10300 Baltimore Boulevard, BARC-West, Building 046, Room 101–A, Beltsville, MD 20705–2350. Submitted material is processed by the Communications and Taxonomic Services Unit and is sent to the appropriate specialist.

Databases

The laboratory has worked extensively at developing various kinds of databases and expert systems and currently is in the process of making this information available on the Internet and through CD–ROM. Some of this information is related to the contents of specific areas of the collection, while other databases catalog groups of insects that are important to agriculture. A large database called BIOTA (Biosystematic Information on Terrestrial Arthropods) is currently being developed that will be a checklist of the insects and mites of North America.

Research

Research in SEL generally is directed toward insect groups of economic importance to American agriculture. Because of possible overlap, great care is taken to avoid duplication of effort between USDA and Smithsonian systematists, and assignments of research areas and responsibility for curation of the collection are carefully coordinated. The research record of SEL is impressive. From 1991 to 1993, the laboratory published more than 130 peer-reviewed research publications, among which are many major revisionary works and books.

The collection is enhanced through accession of valuable specimens submitted for identification and acquired through research and field work endeavors.

The research leader of SEL is Manya B. Stoetzel. The laboratory is divided into three research units, which are organized mainly by ordinal category. Each unit is coordinated by a unit leader.

Acari. The Acari (mite) collection and staff are located at the USDA–ARS in Beltsville, MD, Buildings 046 (Room 102) and 047 (Room 103). The associated library consists of 130 volumes and 95 linear feet of reprints. The collection has about 250,000 slides and 1,925 primary types. The SEL staff includes R.L. Smiley (retired, resident cooperating scientist).

Research on mites began in 1880 with the USDA employee N. Banks, who published in 1915 the first English handbook on mites. Banks was succeeded by USDA acarologists H.E. Ewing, E.W. Baker, and R.L. Smiley. Because of Baker's many outstanding contributions on acarine classification, systematics,

and taxonomy, his peers honored him as the "Father of Modern Day Acarology." Even though he retired in 1987, he continued to perform research on plant-feeding mites until 1996, when he moved to the Philippines.

The collection is especially strong in groups of economic concern to agriculture. Those well represented are the Tetranychoidea, Cheyletoidea, Eriophyoidea (H.H. Keifer's collection), Hydrahnoidea (I.M. Newell's collection), American parasitic and predaceous Mesostigmata, Phytoseiidae, Trombiculidae, and stored-product and bee mites. Many specimens have been studied by Baker, Denmark, DeLeon, Fain, Ewing, Jacot, Johnston, McGregor, Norton, O'Connor, and Smiley.

Recent and future major applications of research include an encyclopedia of H.H. Keifer's studies on the plant-feeding eriophyid mites, a book on mites parasitic on honey bees, and publications on the spider mites of Yemen and the Tenuipalpidae (false spider mites) of the continental United States.

Aleyrodidae. The Aleyrodidae (whitefly) collection and staff are located at the USDA–ARS in Beltsville, MD, Building 012, Room 7–1. The collection has about 19,000 slides and 6,400 envelopes of dry material representing about 482 types and 768 species. The SEL staff members are S. Nakahara and L.M. Russell (retired, resident cooperating scientist). The Aleyrodidae collection was built principally through the efforts of A.C. Baker, A.L. Quaintance, and L.M. Russell.

Recent and future major areas of SEL research include an in-depth study of species in several New World genera and other whiteflies of the contiguous United States, a revision of the genus *Aleurocybotus*, and a description of a new subfamily by L.M. Russell.

Aphidoidea. The Aphidoidea (aphid, phylloxeran, and adelgid) collections are located at the USDA–ARS in Beltsville, MD, Building 012, Room 6. The aphid collection includes 78,000 slides representing 2,250 species. The associated library includes 200 volumes and 34 linear feet of reprints. The SEL staff includes M.B. Stoetzel and L.M. Russell (retired, resident cooperating scientist).

The collections are strong in species collected in quarantine. Specimens are mostly from the United States, Europe, and Asia. These collections were built principally through the efforts of Baker, Pergandé, Quaintance, and Russell. They contain types and identified specimens described and studied by Baker, Fitch, Hottes, Mason, Pepper, Pergandé, Quaintance, Riley, Robinson, Russell, Strom, and Tissot.

Recent and future major areas of SEL research on aphids include the biosystematics of species in the genera *Diuraphis* and *Toxoptera*, a revision of the Phylloxeridae of the world, and notes on *Cerataphis brasiliensis* with a key to *Cerataphis* species living on palms and orchids.

Auchenorrhyncha. The Auchenorrhyncha (leafhopper and planthopper) collection is located on the third floor (west wing) of NMNH in Washington, DC.

The associated library includes 250 volumes and 48 linear feet of reprints. The collection is stored in 1,550 drawers and has about 2,400 holotypes. The SEL staff includes S.H. McKamey.

The first full-time Auchenorrhyncha homopterist associated with the USNM collection was P.W. Oman, who was employed by the USDA in 1931. Since then J.S. Caldwell, J.P. Kramer, and D.A. Young have served as USDA homopterists. The strength of the Auchenorrhyncha collection is in the Cicadellidae, owing to the efforts of Kramer, Oman, and Young. Major acquisitions incorporated in the Auchenorrhyncha holdings are the collections of Baker, Ball, Buys, Caldwell, Funkhouser, Goding, Hacker, McAtee, and Uhler. The collection also contains many types described by Davis, Fennah, Kramer, Osborn, and Van Duzee.

Coccoidea. The Coccoidea (scale insects) collection and staff are located at the USDA–ARS in Beltsville, MD, Building 046, Room 102, and Building 047, Room 102. The associated library includes 200 volumes and 40 linear feet of reprints. The collection consists of 140,000 slides and has 500 primary types. Also included is a large collection of unmounted dry material that contains several million specimens. D.R. Miller, an SEL staff member, is responsible for the determination of scales except those submitted by U.S. port-of-entry identifiers, for whom D.M. Odermatt provides identifications. E.R. Morrison, H. Morrison, S. Nakahara, L.M. Russell, M.B. Stoetzel, and D.J. Williams have also worked on scale insects.

The scale insect collection has developed into one of the most important in the world primarily through the efforts of Morrison (of USDA). Other USDA contributors are Marlatt and Russell. The collection is especially strong in New World material but also is well represented in material from Africa and Australia. Well-represented groups include Asterolecaniidae, Diaspididae, Margarodidae, Ortheziidae, and Pseudococcidae. Major collections are those of Brain, Comstock, Ehrhorn, and Maskell (in part). The collection also contains many types contributed by Cockerell, Ferris, Morrison, and Russell.

Recent and future major areas or applications of SEL research include a revision of Micrococcidae of the world, an analysis of the manna mealybugs as potential biological control agents of salt cedar, the phylogeny of the armored scales, a handbook on the economic armored scales of the United States, a revision of the *Pseudococcus maritimus* group of mealybugs, and a catalog of the scale insects of the world.

A database is near completion that gives an inventory of the species in the Coccoidea collection. The scale insects from North America have been added to the BIOTA database. A joint research project is under way to create an electronic database of the scale insects of the world. This database is accessible on the web at <http://www.sel.barc.usda.gov/scalenet.htm>.

Coleoptera. The Coleoptera (beetle) collection and staff are located on the sixth floor (west wing) of NMNH in Washington, DC. The associated library includes 1,060 volumes and 200 linear feet of reprints. The Coleoptera collection consists of more than 7 million specimens stored in about 12,000 drawers and includes nearly 20,000 primary types. The SEL staff working on Coleoptera

includes Steven W. Lingafelter, Natalia J. Vandenberg, and Donald M. Anderson (retired, resident cooperating scientist). The Smithsonian staff working on Coleoptera comprises Terry L. Erwin and Paul J. Spangler.

The core of the Coleoptera collection was formed in 1881, when the general USDA collection was transferred to the USNM. The appointment of E.A. Schwarz (USDA) in 1897 as honorary curator of Coleoptera further increased the size of the collection because the large and valuable Hubbard and Schwarz collection was donated, making the USNM collection one of the largest in the world. Since the early 1900's, distinguished coleopterists have been associated with the USNM collection. Among these, USDA employees have included D.M. Anderson, W.H. Anderson, R.H. Arnett, Jr., H.S. Barber, R.S. Beal, M.W. Blackman, R.E. Blackwelder (subsequently with USNM), A.G. Boving, J.C. Bridwell, L.L. Buchanan, E.A. Chapin (subsequently with USNM), W.S. Fisher, R.D. Gordon, J.M. Kingsolver, J. Pakaluk, W.D. Pierce, J.G. Rozen, Jr., P.J. Spangler (subsequently with USNM), T.J. Spilman, G.B. Vogt, L.M. Walkley, R.E. Warner, and D.R. Whitehead.

The collection is strongest in Western Hemisphere species, especially in the Anobiidae, aquatic and semiaquatic families, Bruchidae, Buprestidae, Carabidae, Cerambycidae, Chrysomelidae, Cicindellidae, Cleridae, Coccinellidae, immature Coleoptera, Curculionidae, Elateridae, Lampyridae, Mordellidae, Oedemeridae, Phengodidae, Scarabaeidae, Scolytidae, and Neotropical Staphylinidae.

Major collections are those of Baker, Barber, Barber and Schwarz, Belfrage, Blackman, Bovie, Burke, Cartwright, Casey, Chapin, Dieke, Eggers, Erwin, Halik and Daguerre, Harriman, Hopkins, Hubbard and Schwarz, Kissinger, Koebele, Lane, Linell, Mac Swain, Monros, Morrison, Murayama, Pena, Riley, Robinson and Shoemaker, Rosenberg, Schaeffer, Sherman, Smith, Tippman, Turner, and Wickham.

Recent and future major areas or applications of SEL research include investigations on the larvae of the Coccinellidae of the New World, continued publication of a multivolume work on the Neotropical Coccinellidae, preparation of a handbook for the identification of alticine leaf beetles associated with leafy spurge, examination of the systematics of immature Curculionoidea and the Baridinae, and revision of the flea beetle genus *Chaetocnema*.

Diptera. The Diptera (fly) collection and staff are located primarily on the sixth floor (west wing) of NMNH in Washington, DC. The associated library includes 500 volumes and 550 linear feet of reprints. The collection comprises more than 7,000 drawers of pinned specimens, 470,000 slide-mounted specimens, and 19 quarter cases of specimens in alcohol. About 20,500 primary types are included. The SEL staff includes R.J. Gagné (retired, resident cooperating scientist), A.L. Norrbom (unit leader of Coleoptera and Diptera Unit), F.C. Thompson, and N.E. Woodley. The Smithsonian dipterist is W.N. Mathis. The Walter Reed Biosystematics Unit at the Smithsonian Institution's Museum Support Facility in Silver Hill, MD, curates the Culicidae and other biting flies. Staff employed by the Army to work on mosquitos at this facility are L. Rveda, E.L. Peyton, and R.C. Wilkerson.

In 1886, the USDA appointed S.W. Williston as the first dipterist associated with the USNM Diptera collection. Since then, many USDA specialists have worked on the taxonomy of Diptera, including D.W. Coquillett, R.H. Foote, C.T. Greene, D.G. Hall, L. Knutson, J.R. Malloch, R.V. Peterson, C.W. Sabrosky, R.C. Shannon, G.C. Steyskal, A. Stone, C.H.T. Townsend, and W.W. Wirth. Other than W. Mathis, J.M. Aldrich was the only dipterist employed by the Smithsonian.

The collection is perhaps the best in the world, with Nearctic and Neotropical Diptera being especially well represented. The best represented groups are Agromyzidae, Asilidae, Bombyliidae, Calliphoridae, Cecidomyiidae, Ceratopogonidae, Chloropidae, Culicidae, Empididae, Ephydridae, Muscidae, Sarcophagidae, Scatopsidae, Sciaroidea, Sciomyzidae, Tachinidae, Tephritidae, and Tipulidae.

Major additions to the collection have been provided by Aldrich, Baranov, Belkin, Bromley, Burgess, Coquillett, Dyar, Gagné, Hoogstraal, King, Knight, Ludlow, Malloch, Mathis, Melander, Norrbom, Painter, Pritchard, Roseboom, Shannon, Steyskal, Sturtevant, Thompson, Thurman, Williston, and Wirth. An important acquisition is the Alexander crane fly collection, which is probably the best private collection of flies ever amassed. It includes more than 11,000 of the 14,000 species of crane flies and over 8,000 holotypes. The mosquito collection has been significantly expanded in recent years by two Smithsonian contracts with the U.S. Army. By means of these contracts, the former Southeast Asia Mosquito Project and the present Walter Reed Biosystematics Unit have accessioned more than 250,000 specimens of mosquitoes. The collection is improved daily by the retention of specimens submitted for identification from all parts of the world.

Recent and future major areas and applications of SEL research include the following: generic revisions of predaceous cecidomyiids and of gall midges feeding on weeds, including tamarisk and paperbark, and crops such as blueberries, blackberries, and grasses; revisions of Nearctic and Neotropical genera of Tephritidae, including *Anastrepha*, *Eutreta*, and *Pseudophorellia*, and Neotropical species of *Dasiops* (Lonchaeidae) that attack *Passiflora;* a handbook of Central American and Mexican fruit flies; a Neotropical Tephritidae specimen database (1,200 records); a revision of the Middle American flower fly fauna; a generic revision of *Belvosia* (Tachinidae) as well as some small genera; and revisions of various groups of Stratiomyidae.

The Diptera staff is very active in the management of computerized information. This staff is leading an international effort to develop a biosystematic database of world Diptera, parts of which are being disseminated as they are completed. Currently this database includes all of the family-group names (4,296 records), genus-group names (18,000), and some species-group names (70,742 records). The final database will probably include more than 250,000 records and will be completed before the next century. Completed databases include the Systematic Database of Nearctic Diptera, the basic nomenclatural data for all flies found in North America, the first fascicle of World Diptera (the Tephritidae or fruit flies), and a catalog of the family-group names. The Diptera staff is building a species inventory of the Diptera in National Insect

Collections; some 18,000 records are already available on the Smithsonian's World Wide Web site <http://nmnhwww.si.edu/departments/entom.html>. The entire species inventory should be completed in 1999.

The staff has begun a pilot project to investigate the means and costs of making specimen-based information available in various digital media, from CD–ROM to Internet World Wide Web pages. Initial concentration will be on local and Costa Rican specimens. A resource directory for Dipteran Systematics is also maintained, which contains address records for about 1,825 workers. Some 1,150 specialists also provided information on their research interests. Two printed versions have been distributed (1990, 1994); the data are also periodically merged with the on-line directory of entomologists maintained by the Smithsonian Department of Entomology. An expert system for the identification of fruit flies of importance to agriculture is complete.

Heteroptera. The Heteroptera (true bug) collection and staff are located on the third floor (west wing) of NMNH in Washington, DC. The associated library includes 300 volumes and 70 linear feet of reprints. The Heteroptera collection occupies about 2,500 drawers and contains about 4,000 holotypes. Staff members are T.J. Henry (SEL), D.A. Polhemus (Smithsonian Institution), and R.C. Froeschner (Smithsonian Institution, retired).

In 1898, O. Heidemann was employed by the USDA to study the systematics of the Heteroptera. Since then, the following USDA specialists have undertaken Heteroptera systematic research: P.D. Ashlock, H.G. Barber, R.C. Froeschner (subsequently with the Smithsonian Institution), E.H. Gibson, J.L. Herring, W.L. McAtee, and R.I. Sailer.

The collection is strongest in New World specimens but is also well represented in Philippine material. The collection is especially well represented in the families Aradidae, Cimicidae, Lygaeidae, Miridae, Ochteridae, Phymatidae, and Tingidae. Major collections included are those of Baker, Barber, Carvalho, Drake, Hacker, Knight, Kormilev, McAtee, Pennington, Reed, and Uhler. Many specimens studied by the following heteropterists are in the collection: Carvalho, Harris, Maldonado, Slater, and Usinger.

Recent and future major areas or applications of SEL research include a phylogenetic analysis of the Pentatamomorpha, a phylogenetic analysis of the berytid genera of the world, a monograph of the Berytidae of the Western Hemisphere, a manual of the Miridae of eastern North America, and a manual of the Nabidae of North America.

Hymenoptera. The Hymenoptera (wasp and bee) collection and staff are located on the second floor (hall 27) of NMNH in Washington, DC, except for R.C. Carlson, whose office is at the USDA–ARS in Beltsville, MD, Building 046; R.J. McGinley, whose office is on the third floor of the west wing of NMNH; and T.R. Schultz, whose office is at the Museum Support Facility in Silver Hill, MD. The associated library includes 200 volumes and 400 linear feet of reprints. The Hymenoptera collection consists of about 3 million pinned specimens stored in more than 6,000 drawers and includes more than 15,000 holotypes. The SEL staff working on Hymenoptera consist of R.W. Carlson, E.E. Grissell, M.E.

Schauff (unit leader of Sternorrhyncha, Thysanoptera, Acari Research Unit), and D.R. Smith (unit leader of Hymenoptera, Lepidoptera, Orthoptera Research Unit). The Smithsonian staff working on Hymenoptera include R.J. McGinley, T.R. Schultz, and K.V. Krombein (retired).

The nucleus of the Hymenoptera collection was formed by such early workers as Riley, Pergandé, Schwarz, and Howard, but the USNM Hymenoptera holdings first acquired the status of a major collection with the acquisition of the Ashmead collection in 1898. Ashmead was appointed in 1887 by the USDA to work on insect pests and their parasites. From 1897 to 1908, he was employed by the Smithsonian Institution as assistant curator and thus was the first USNM hymenopterist. Crawford succeeded Ashmead as assistant curator in 1908 and centered his research on the Chalcidoidea. During Crawford's tenure, several USDA scientists were assigned to the museum to work principally on parasitic wasps and sawflies. These individuals include Cushman, Gahan, Girault, Rohwer, and Viereck. Other USDA hymenopterists associated with the collection include Burks, Gordh, Krombein (subsequently with USNM), Mann, Marlatt, Marsh, Menke, Muesebeck, Sandhouse, Smith, Townes, Walkley, and Weld.

Areas of the collection especially well represented include Aculeata, Chalcidoidea, Cynipoidea, Formicidae, Ichneumonoidea, Proctotrupoidea, and Symphyta. Major collections are those of Ashmead, Baker, Bugbee, Cooper, Hurd, Krombein, Mann, Priesner, Stelfox, and Tsuneki.

Recent and future major areas or applications of SEL research include an identification manual to world seed-feeding Chalcidoidea; a revision of several North American chalcidoid genera; keys to parasites of citrus leafminer, *Heliothis*, and the gypsy moth; a key to New World genera of Braconidae; revisionary studies in Rogadinae; revision of the family Tenthredinidae for the Americas south of the United States; revision of the Symphyta for the eastern United States; a world catalog of Sphecidae; and a revision of the caterpillar predator genus *Ammophila* for the New World.

Collection databases have been developed for Eulophidae, Aphelinidae, Tanaostigmatidae, and Toryminae (Torymidae).

Isoptera. The Isoptera (termite) collection is located on the ground floor of the Smithsonian Institution's Museum Support Center, Silver Hill, MD. The associated library includes about 100 volumes and 60 linear feet of reprints. The collection consists of 240,000 specimens (1,286 species) and includes 943 types. At present D.A. Nickle is the only SEL staff member conducting research on termites.

The termite collection is one of the largest in the world, primarily through the efforts of T.E. Snyder (of USDA). Extensive additions have recently been made to the collection by D.A. Nickle and the late M.S. Collins. The collection has worldwide representation and is especially rich in species from the West Indies, Central America, and the Amazon Basin.

Recent and future major applications of SEL research include books on the North and South American termites.

Lepidoptera. The Lepidoptera (moth and butterfly) collection and staff are located on the second floor (hall 30) of NMNH. The library resources relating to Lepidoptera consist of 2,000 volumes and 370 linear feet of reprints in file cabinets. The Lepidoptera collection occupies 27,483 drawers and is estimated to contain more than 4 million specimens, including over 25,000 primary types. The larval collection is one of the largest in the world, occupying 1,132 storage racks (specimens in alcohol) and 132 drawers (inflated larvae). The larval collection is estimated to contain about 123,000 specimens. Included also are 131 slide cabinets containing about 100,000 microscope slides, mainly of moth genitalia. The SEL research staff working on Lepidoptera includes J.W. Brown, D.C. Ferguson (retired, resident cooperating scientist), M.G. Pogue, and M.A. Solis; the Smithsonian staff includes J.M. Burns, D.R. Davis, and R.K. Robbins.

The first specialist to work on Lepidoptera at the USNM was J.B. Smith, who was employed by the Smithsonian Institution in 1885. He was followed by a series of USDA entomologists, including F. Benjamin, A. Busck, H.W. Capps, J.F.G. Clarke (subsequently employed by the USNM), H.G. Dyar, W.D. Field (subsequently employed by the USNM), J.G. Franclemont, C. Heinrich, R.W. Hodges, R.W. Poole, W. Schaus, E.L. Todd, and D.M. Weisman.

The collection is strongest in Nearctic material, rich in Neotropical and Palearctic species, and progressively less rich in Oceanic, Oriental, Australian, and African material. Especially well-represented exotic groups include Lycaenidae and Pieridae; European and Japanese microlepidoptera; and Taiwanese, Philippine, and Szechwan moths in general.

Major acquisitions that have been incorporated into the museum holdings over the years are the collections of Alfieri (Egypt), Baker (Philippines, Malaysia), Baker (Oregon moths, especially Geometridae), Barnes (North America, including types of Barnes & McDunnough, Guenee, Boisduval, Kearfott, Hill, Taylor, and the Merrick collection), Blackmore (British Columbia), Blanchard (Texas), Box (sugarcane-feeding Pyralidae), Brighton Museum (British microlepidoptera), Brooklyn Museum (North America), Brower (North America, especially Maine), Clarke (Pacific Northwest), Dognin (South America), Dyar (North America and Neotropics), Engelhardt (Sesiidae), Ferguson (North America, especially Atlantic Provinces), Fernald (North American, including some type material of Fernald, Fitch, Fish, Walsingham, Hulst, Packard, and Grote), Field (Japanese and European butterflies), Franclemont (North American Saturniidae, Sphingidae, and microlepidoptera), Graef (North America), Grossbeck (North America), Hodges (North American microlepidoptera), Issiki (Japanese microlepidoptera), Jackh (Texas and Palearctic microlepidoptera), Kawabe (Japanese and Taiwanese microlepidoptera), McAlpine (Riodinidae), Neumoegen (North America), Philpott (New Zealand microlepidoptera), Schaus (mostly Tropical America), and Smyth (American and exotic Lepidoptera). The collection also contains many of the types of Smith and of many others who studied USNM material, including Diakonoff, Munroe, Rindge, Shaffer, and Warren.

The largest acquisitions were the Barnes collection (nearly a half million specimens) purchased by the USDA in 1931, the Baker collection (300,000

specimens) donated in 1928, and the Schaus collection (200,000 specimens) donated in 1901 and following years. The Barnes and Schaus material accounted for most of the North American and Tropical American Lepidoptera holdings, respectively, for over 40 years. However, with renewed interest in field work and curation, current USDA and Smithsonian lepidopterists have greatly improved the collection, adding about as many specimens from their own collecting as did all of their staff predecessors combined.

Recent and future major areas or applications of SEL research on Lepidoptera include the following: continued revisionary works for the publication series *Moths of America North of Mexico*, including a detailed analysis of the 195 species of *Chionodes* (Gelechiidae) and an illustrated key to the 85 or more genera of North American Gelechiidae; revisions of the Lithosiinae (Arctiidae), the Macariini (Geometridae), and Epipaschiinae (Pyralidae); inventories of the pyraloid moths of Costa Rica and the macrolepidoptera (including Pyraloidea) of Maryland; a phylogenetic analysis of the subfamilies of Crambidae and *Ostrinia* (corn borer complex); and a revision of the temperate Eurasian species of *Lymantria* (gypsy moth genus).

Various databases on Lepidoptera are being developed or maintained. The very large database of world Noctuidae and its associated bibliography, already published, is being kept current. Specimen label databases for *Chionodes* (Gelechiidae) (about 18,000 entries) and North American cuculliine and simpistine Noctuidae (30,000–40,000 entries) are active and growing. Mapping programs are also in use. A pilot project to test the feasibility of developing a computerized library of colored photos of larvae (with full data) has been started with the digitizing of about 200 slides (through the collaboration of M.E. Schauff). The computerized library allows the valuable photographs to be archived so that they are protected from deterioration and yet are easy to reference for making determinations or for publishing and creating prints and CD–ROM's.

Orthoptera. The Orthoptera (orthopteroid) collection and staff are located on the third floor (west wing) of NMNH in Washington, DC. The associated library includes 550 volumes and 60 linear feet of reprints. The collection is stored in 2,500 drawers and 6 quarter cases of alcohol material and has nearly 700 primary types. The SEL staff member is D.A. Nickle. The collections of mantids, cockroaches, and walkingsticks are located at the Museum Support Center in Silver Hill, MD.

Three USDA orthopterists have concentrated their research and identification efforts on this group of insects. A.N. Caudell was employed in 1898, A.B. Gurney in 1936, and D.A. Nickle in 1979. The collection is strongest in U.S. *Melanoplus* grasshoppers, Neotropical cockroaches and katydids, and grylloblattids. Major collections incorporated into the USNM holdings are those of Baker, Daguerre, and Riley.

Current and future major areas of research include revisions of Neotropical katydid genera, the mole cricket genus *Scapteriscus*, and the cockroach genus *Arenivega*.

Psylloidea. The Psylloidea (psylloid) collection is located at USDA–ARS in Beltsville, MD, Building 046, Room 102. D.R. Miller is responsible for identifications but does not perform research on the group. The psyllid collection has 21,300 pinned specimens, 2,400 slides, 3 drawers of psyllids on their hosts, and 90 types, representing 300 species.

Major contributors to the psyllid collections include Caldwell, Crawford, Riley, Russell, Schwarz, and Tuthill.

Thysanoptera. The Thysanoptera (thrips) collection and staff are located at USDA–ARS in Beltsville, MD, Building 012, Room 7–1. S. Nakahara does research and identifications on thrips. The associated Thysanoptera library includes 300 volumes and 22 linear feet of reprints. The collection has about 100,000 specimens representing about 2,100 types and 2,800 species.

The Thysanoptera collection was started by T. Pergandé (USDA) before 1900. No full-time thysanopterist was employed by the USDA until the late 1930's, although identifications were provided by A.C. Morgan and J.R. Watson. USDA thysanopterists include F. Andre (1938–40), J.C. Crawford (1940–50), and K. O'Neill (1950–75). Geographic areas best represented by the collection are North America, western Europe, India, and Central and South America. The most important acquisition was the purchase of the J.D. Hood collection in 1965, which more than doubled the size of the Thysanoptera collection.

Recent and future major areas or applications of SEL research include revisions of several genera in the Nearctic Region and a Handbook of Nearctic species of the family Thripidae north of Mexico.

Selected Achievements

1881	Published first major revision of scale insects of North America, including many pest species
1885	Published first comprehensive systematic treatise of chalcidoid parasites in North America
1897	Published first comprehensive revision of tachinid flies of America north of Mexico, including many important parasites
1903	Cataloged Lepidoptera of North America, including 6,622 species, with synopsis of moth and butterfly literature
1907	Published first major revision of family Decticinae in North America, which included 66 species and pests like Mormon cricket
1913	Classified the whiteflies (Aleyrodidae) of the world
1923	Revised moth family Olethreutidae of North America, including conifer and fruit tree pests, totaling 700 species
1925	Published and later revised (1952) classification of ensign scales, family Ortheziidae of the world, including 90 species
1928	Classified ground pearl family Margarodidae, including 250 species and such pests as cottony cushion scale

Selected Achievements (cont.)

1931	Published first major synopsis of larval forms of beetles
1935	Published textbook on insect morphology, which standardized structural terminology
1938	Established classification of 200 Nearctic species of horseflies in subfamily Tabaninae
1941	Revised moth family Oecophoridae of North America, including 117 species and several household and vegetable pests
1941	Published classification of 150 pit scale species of the world
1942	Established classification of fruit fly genus *Anastrepha* of the world, including such important pests as Mexican fruit fly
1946	Published catalog of beetles of Mexico, West Indies, and Central and South America, including 50,000 species
1949	Cataloged termites of the world, including 2,500 species
1951	Cataloged Hymenoptera of America north of Mexico, including over 18,000 species
1952	Published textbook on study of mites (serves as basis for acarology curricula throughout the world)
1954	Revised termites of United States and Canada
1955–58	Published comprehensive treatise on plant-feeding spider mites of the world
1955	Published first of eight volumes on microlepidopterous type specimens of Meyrick, including illustrations of 5,000 species
1956	Revised moth subfamily Phycitinae of New World, including over 700 species and many stored-product and forest pests
1958	Established new classification of mites of the world
1965	Cataloged Diptera of America north of Mexico, including more than 16,000 species
1966	Published annotated list of generic names of scale insects
1968–89	Made extensive contributions to catalogs of Diptera of Americas south of United States, Oriental Region, Australasian and Oceanian Regions, and Afrotropical Region
1971–95	Published 10 fascicles of *The Moths of America North of Mexico*, including Sphingidae, Saturniidae, Cosmopterigidae, Lymantriidae, Oecophoridae, Geometrinae, Dichomeridinae, Plusiinae, Cuculliinae, Stiriinae, and Psaphidinae
1975	Revised Epilachninae of Western Hemisphere, including 288 species and pests like Mexican bean beetle and squash beetle
1976	Published book on sphecid wasps, which included 7,634 species

1976	Revised lady beetle tribe Scymnini with important predators
1976–95	Managed, edited, and produced *The Moths of America North of Mexico* (nearly 2,000 pages)
1978	Published catalog of wasps Siricidae, Xyelidae, Xiphydriidae, and Pergidae
1979	Published three-volume catalog on Hymenoptera of America north of Mexico
1981–89	Contributed 27 chapters to three-volume *Manual of Nearctic Diptera*
1982	Wrote illustrated guide to plant abnormalities caused by eriophyid mites in North America
1985	Reclassified genera of a large section of Arctiini moths
1985	Discovered host alternation in Phylloxeridae
1986	Classified the whitefly genus *Aleurocerus*
1987	Published New World revision of moth genus *Pero*
1987	Published an identification manual for North American genera of parasitic wasp family Braconidae
1987	Completed catalog on true bugs of United States and Canada
1987	Produced book on false spider mites of Mexico
1989	Published book on 900 species of plant-feeding gall midges of North America
1989	Completed 1,314-page catalog of all scientific names of Noctuidae with complete bibliography
1990	Published *Handbook of Families of Nearctic Chalcidoidea* wasps
1991	Completed research on Lepidoptera of Bermuda, demonstrated long-range migratory tendencies in many American species
1991	Published catalog of 1,200 genus group names of Symphyta wasps
1991	Contributed to comprehensive book on immature insects
1991	Wrote chapters of identification manual on insects and mites in food
1992	Synthesized distribution and biology of Holarctic mirid bugs
1992	Classified predatory mite family Cunaxidae
1993	Completed an analysis of the eriococcid scales of the eastern United States
1993	Published handbook of the 300 fruit fly species of the United States and Canada
1993	Completed phylogenetic analysis and reclassification of genera of pyralid moths of *Pococera* complex and world checklist of Epipaschiinae

Selected Achievements (cont.)

1993	Published revision and phylogenetic analysis of *Heliothis* virescens group (tobacco budworm moths, Noctuidae)
1993	Revised leaf beetles in Criocerinae
1994	Classified genus *Thrips* of New World
1994	Completed guide to spider mites of United States
1994	Wrote book on gall midges of Neotropics
1995	Published phylogenetic classification of parasitic wasps in subfamily Toryminae, including world catalog of species
1995	Published checklist of Neotropical Epipaschiinae, Pyralinae, Chrysauginae (Pyralidae)
1995	Established new classification of torymine wasps
1996	Revised *Chaetocnema* flea beetles in the United States and Canada
1996	Published book on eriophyoid mites of the United States
1996	Completed analysis of grape mealybug complex
1997	Analyzed and revised the stiltbug genera of the world (Heteroptera: Berytidae)
1997	Monographed the stiltbugs of the Western Hemisphere

U.S. National Pollinating Insects Collection

By Terry Griswold

Location U.S. Department of Agriculture, Agricultural Research Service, Bee Biology and Systematics Laboratory, Utah State University, Logan, UT 84322–5310

Loans To recognized institutions and scientists

Associated libraries 15,000 reprints

Number of accessions 6,850 species of bees (worldwide) and 2,850 species of wasps and other insect nest associates in 1,600 museum drawers (800,000 specimens)

Types Many, mostly paratypes

Curator Terry Griswold
Phone: (801) 797–2526 • fax: (801) 797–0461
e-mail: <tgris@cc.usu.edu>

Home page: none.

Background

The U.S. National Pollinating Insects Collection provides the basis for systematic and biological studies on pollinating insects from many parts of the world. The collection was started in 1947 by G.E. Bohart. It has expanded rapidly through acquisitions of biological material and exchanges with other institutions. Bohart contributed many specimens, as have P.F. Torchio, F.D. Parker, V.J. Tepedino, and T. Griswold. Bohart, Parker, and Torchio are now Federal collaborators and have been active in working with the collection and providing new accessions.

Identification Service

Each year many requests for identifications of pollinating insects are received directly from research scientists, bee systematists, graduate students, state and county farm advisors and extension agents, bee breeders, seed growers, and others. Identifications of bees are also provided for the Systematic Entomology Laboratory under a cooperative agreement. An average of 44 lots (4,500 specimens) are processed annually. Additional requests are made by taxpayers for bee information, including the analysis and causes of bee stock losses due to parasites or predators.

Databases

An inventory of the collection provides a list of holdings, numbers of specimens per species, and geographic distribution. A specimen-based databank of the bees in the collection has been undertaken and is more than half done, with completion anticipated in 1997 or 1998. Data capture of all future incoming material will be accomplished using individual specimen bar codes, facilitating the electronic exchange of information. A computerized checklist of North American bees (including bees from Central America) has been completed and will be regularly updated. Computerized catalogs of Megachilidae and Colletidae are in development. These databases are not currently available on the World Wide Web. Inquiries should be addressed to the Bee Biology and Systematics Laboratory.

Research

The U.S. National Pollinating Insects Collection is essential in promoting the ARS missions of improving crop pollination, conserving genetic resources, and preserving biodiversity. The Bee Biology and Systematics Laboratory is responsible for studies of pollinating insects, primarily bees, including their adult and immature systematics, biology, associated predators and parasites, role in plant pollination, and use as crop pollinators. As a rich resource of nearly 4,000 species of native bees in the United States alone, this collection aids in accurate identifications of potential pollinators. Such identifications are essential for ongoing basic and applied pollination research. Systematic research focuses on bee taxa with high potential for management (Megachilidae) and their parasites (*Stelis*, *Coelioxys*). The importance of pollinators in the maintenance of native ecosystems and particularly of rare plant species is a secondary focus of research.

Selected Achievements

1953	Domesticated first native bee, *Nomia melanderi*, resulting in over a twentyfold increase in alfalfa seed production
1960	Assisted in developing multimillion-dollar leafcutter bee industry
1973	Developed method to control leafcutter bee parasite, saving the alfalfa seed industry millions of dollars
1975	Developed blue orchard bee, *Osmia lignaria*, which augments honey bee pollination of orchard crops
1990	Developed *Osmia ribifloris* as pollinator of highbush blueberry
1993	Analyzed the pollination and reproductive biology of 26 species of threatened and endangered plant species in the western United States (fig. 15)

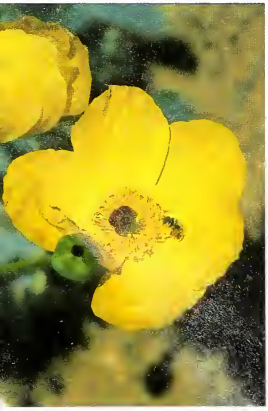

Figure 15. *Perdita meconis*, a new species pollinating *Arctomecon californica*, one of many rare plants dependent on native bees for reproduction

U.S. Rangeland Grasshopper Collection

By James R. Fisher

Location U.S. Department of Agriculture, Agricultural Research Service, Sidney Agricultural Research Center, 1500 N. Central, Sidney, MT 59270

Loans To recognized institutions and scientists

Associated libraries 200 volumes; 2,900 reprints; 70 systematic reprints

Number of accessions 9,000 specimens; 270 species

Types 2 paratypes

Curator Jerome Onsager
Phone: (406) 482–2020 • fax: (406) 482–5038
e-mail: <onsagerj@sidney.ars.usda.gov>

Home page: none.

The U.S. Rangeland Grasshopper Collection contains short-horned grasshopper species from different habitats of the western United States. It is a major resource for the genus *Melanoplus* (fig. 16) from western North America; of 300 species worldwide, 72 are represented in the collection. This genus contains three of the most economically important species of grasshoppers in the New World.

The 2,900 reprints in the collection's library are worldwide in scope and are primarily on Acridids. Much of the information is now historical, as articles have been continuously added since the start of grasshopper studies in Montana in the late 1920's. The library also contains an archive of correspondence pertaining to grasshopper abatement campaigns that took place between 1900 and 1950.

Figure 16. *Melanoplus sanguinipes*, the lesser migratory grasshopper. This species is the most destructive grasshopper in North America.

Background

The collection was started in the early 1920's by Robert L. Shotwell and Steward Lockwood, who were employed by the Bureau of Entomology, U.S. Department of Agriculture, in Billings, MT. Most of the specimens in their collection were obtained in previous surveys throughout the United States by government entomologists. In 1930, the collection was moved to Montana State University. John R. Parker was in charge of the collection, and the laboratory became known as the Grasshopper and Mormon Cricket Laboratory. During this time, Fred Skoog and Louis Spain were the curators, and many specimens were added. In 1961, when the collection was moved to another building at the university, Frank Cowan was in charge of the laboratory. George Hewitt was responsible for the collection from 1970 to 1989. In 1987, the collection was moved to the library in the new Rangeland Insect Laboratory building on the campus of Montana State University. In 1996, the collection was moved to the Sidney Agricultural Research Center, in Sidney, MT, when the Rangeland Insect Laboratory in Bozeman was closed. Jerome Onsager presently serves as curator of the collection. Although the collection has grown slowly since the 1960's, it is used extensively in support of identification services, for historic range records, and as a voucher repository for scientists from the Rangeland Insect Laboratory and many other locations.

Identification Service

Identifications are made for Federal, state, and private research scientists and for others concerned with pest problems. The collection has been used to assist scientists in locating potential collecting sites for species used in research and is a source of specimens for taxonomic revisions. Information has been made available to movie producers for filming pictures with grasshoppers. In addition to the preserved specimen collection, the laboratory maintains colonies of several important species of rangeland grasshoppers. Live grasshoppers are used for active local research programs and to fill needs as requested by the pest control and motion picture industries, researchers within USDA, and other public agencies and institutions.

Research

The Rangeland Insect Laboratory was located at Bozeman, MT, for over 65 years and was incorporated into the Sidney Agricultural Research Center in 1996. The laboratory is primarily responsible for developing management strategies for insect pests and weeds of rangeland and rangeland-associated agriculture throughout the western United States. The lab is staffed with 5 research scientists, 1 support scientist, and 14 clerical and technical employees. The major emphasis of the laboratory is on crop management of rangeland and rangeland-associated agriculture for the Northern Plains. Studies are performed on biological control (protozoa, viruses, and other pathogens) of insect pests and weeds, insecticide application and delivery, and soil dynamics and hydrology.

Selected Achievements

1929	Performed first descriptive work on biology and control of Mormon cricket
1930's	Developed baits and tillage methods for control of grasshoppers on arable land in the Northern Great Plains
1940's to 1950's	Developed baseline biological studies on *Melanoplus bivittatus* and *Camnula pellucida*
1970	Described a new species of *Melanoplus (M. lanthanus)* from Montana
1978	Registered *Nosema locustae* as the first protozoan microbial insecticide in the United States
1980's	Developed an improved insecticide bran bait for use on rangeland grasshoppers
1992	Developed Hopper, a decision support system for grasshopper management through a collaborative ARS–APHIS Grasshopper Integrated Pest Management Project
1992	Developed national and state grasshopper detection and prediction maps with data from Geographic Information Systems and survey input from APHIS
1993	Developed a DNA probe to detect entomopoxviruses and *Nosema locustae* in grasshoppers
1994	Demonstrated that grazing management can directly affect the life history, phenology, and survival of rangeland grasshoppers
1995	Developed a model for a major grasshopper pest that predicts hatching within a 10-day period

USDA Nematode Collection

By Zafar Ahmad Handoo, A. Morgan Golden, and Donna M.S. Ellington

Location U.S. Department of Agriculture, Agricultural Research Service, Nematology Laboratory, BARC-West, 10300 Baltimore Boulevard, Building 011A, Room 159, Beltsville, MD 20705–2350

Loans To recognized scientists and institutions

Associated libraries 20,000 reprints and volumes

Number of accessions 34,000 permanent slides and vials; 19,500 species

Types 1,500 species

Curators Zafar A. Handoo, A. Morgan Golden, Donna M.S. Ellington
Phone: (301) 504–6666 • fax: (301) 504–5589
e-mail: <nematax@asrr.arsusda.gov>

Home page <http://www.barc.usda.gov/psi/nem/tax-page.htm>

The U.S. Department of Agriculture (USDA) Nematode Collection at Beltsville, MD, is one of the largest and most valuable international resources of information for nematode taxonomic research and identifications. It is widely used by U.S. and foreign scientists to resolve various taxonomic and nomenclatural problems. Identifications of nematode species within some species complexes are possible only through the use of the collection. It also provides substantial data on nematode hosts, occurrence, and distribution on a worldwide basis.

Figure 17. Slides in the type collection. All type slides and most others are kept in fireproof safes.

The constituent divisions of the USDA Nematode Collection are as follows:

Type collection—for designated types (fig. 17).

General collection—for species from many different hosts and areas, especially useful for comparison and reference purposes and variation studies.

Mass collection—a reservoir for problematical and undescribed taxa, most of which will be studied and described as groups are revised.

Demonstration collection—for exhibits showing symptoms and effects of various kinds of nematodes on a wide range of host plants (fig. 18).

Gerald Thorne collection—for slides of important plant and soil species and higher taxa.

Steiner Mermithid collection—for slides of nematode (mermithid) parasites of insects, with many original types.

Sample records division—for data on all samples and nematodes examined.

Background

From 1908 until his death in 1932, N.A. Cobb did extensive taxonomic research on plant, soil, freshwater, and marine nematodes. In 1918, he was joined by G. Steiner, who made major contributions in taxonomy, including insect parasites, until his retirement in 1956. Concurrently, Gerald Thorne joined USDA in Utah and for the next 38 years made major contributions in nematode taxonomy, almost exclusively in plant and soil forms. Other USDA scientists made significant contributions in taxonomy and other areas of nematology in the Washington, DC, area during the 1920's and 1930's, including B.G. Chitwood, J.R. Christie, and A.L. Taylor.

Most of the specimens used by these earlier workers were retained as individual collections within the agency rather than in an organized, unified system. Unfortunately, over the years, many valuable specimens deteriorated and others were misplaced or their records lost. Extant specimens are being salvaged and incorporated into the USDA Nematode Collection. Fortunately, the Gerald Thorne collection, developed by Thorne in Utah between 1918 and 1956, was well organized and well kept, and now forms an important segment of the present collection.

The USDA Nematode Collection was officially established by A. Morgan Golden in 1960, shortly after initiation of the current nematode taxonomy program. The collection is well organized, and records of all specimens are filed according to genus, species, host, and origin. This is an open-ended system and allows ready retrieval of specimens with pertinent data and also has permitted easy conversion to computerization of collection records.

Growth of the collection resulted from a number of factors, including restudy of material of earlier workers; the deposition of type and other specimens by colleagues in the United States and various foreign countries; the gradual, ongoing incorporation of material identified for researchers and other scientists within the United States and abroad; and the personal collecting and unstinting efforts of A.M. Golden since 1956. Although most of the specimens are plant and soil nematodes, some are insect parasites and free-living soil, freshwater, and marine forms. Most specimens, including all types with pertinent records, are kept in fireproof safes (fig. 17).

Identification Service

Figure 18. Exhibits in demonstration collection

The service responsibilities of the Nematology Laboratory are an essential and important part of a diverse research program in nematology. Each year more than 300 samples of nematodes are received, processed, and examined for nematode identifications by ARS scientists, other Federal and state researchers and regulatory agencies, graduate students, and foreign scientists. Nematode samples often include several different genera and species of both plant-parasitic and soil nematodes.

These identifications provide basic support for biological control projects and diverse research, extension, and control activities of Federal and state agencies and other organizations in the U.S. and abroad. This service provides useful information on nematode hosts, occurrence, and distribution and can reveal new or potentially harmful species of nematodes associated with previously unknown agricultural problems, and aids in the development of quarantine or regulatory procedures to prevent their spread. Also, quick and accurate nematode identifications are provided to inspectors from the Animal and Plant Health Inspection Service (APHIS) for the release of shipments of various foreign crops and wood products detained at various ports for the determination of exotic pests.

Each year, on request, the collection provides loans to various U.S. and foreign scientists for use in taxonomic research, identification, and preparation of monographs. Generally, only a few species of a particular group are loaned to an individual or organization at one time, and loans are made for a limited time. These procedures provide maximum use and availability of valuable scientific material.

Research

The USDA Nematode Collection is the basis for research on systematics, morphology, and identification of soil and plant-parasitic nematodes and serves as a valuable asset for further knowledge or revision of material described earlier. The current staff of the collection (one nematode systematist from the Agricultural Research Service, one support scientist, and one retired volunteer) places major emphasis on taxonomy and identification of economically important plant-parasitic nematodes. New morphometric data and techniques, such as scanning electron microscopy and digitized image analysis measurement systems, are used to characterize and classify any species difficult to identify. Emphasis is placed on the preparation of keys and compendia to major groups of plant-parasitic nematodes to facilitate accurate identification of species.

Databases

The computerization of the USDA Nematode Collection has started, and new accessions are being entered into the database. A broad range of data is stored for each accession, including genus, species, host, origin, collector, date collected, and date received. Included in the taxonomic data are generic names, specific and infraspecific names, distribution records, and taxonomic reference citations.

Descriptive data are now kept in Paradox for Windows 7.0. Online access to the Internet is forthcoming.

Selected Achievements

1949	Produced first modern classification of root-knot nematodes (*Meloidogyne* spp.), providing a sound basis for species identification and development of resistant crop varieties for individual species
1967	Monographed Sphaerularidae, a family of insect parasitic nematodes
1967	Established Encholaimoidea, a new monotypic superfamily phylogenetically linking soil and marine nematodes
1969	Identified and described rice root-knot nematode (*Meloidogyne graminicola* Golden and Birchfield), a major new pest of rice in several countries
1970	Revised Aphelenchoidea, a nematode superfamily containing plant parasites, predators, fungus feeders, and insect parasites
1971	Revised order Tylenchida, containing majority of plant nematodes
1972	Revised insect parasitic nematode family Mermithidae, presenting new information on life cycles and host ranges
1974	Documented first occurrence in United States of oat cyst nematode (*Heterodera avenae* Wollenweber), a major world-wide pest of cereals
1980	Identified and described for the first time Columbia root-knot nematode (*Meloidogyne chitwoodi* Golden et al.), a major new pest of potato in the United States and foreign countries
1983	Monographed Heteroderidae, a family of worldwide economically important cyst-forming nematode genera and species
1983	Documented first occurrence in United States of corn cyst nematode *(Heterodera zeae)*, an economically important pest of corn
1986	Published a comprehensive book chapter on morphology and identification of cyst nematodes (Heteroderidae) of the world

Selected Achievements (cont.)

1989	Published key and compendium to the 63 species of the genus *Pratylenchus* (lesion nematodes), an economically important group of plant-parasitic nematodes attacking a wide variety of crops throughout the world
1989 and 1992	Published survey results of many kinds of nematodes on a wide variety of economically important crops in Arkansas, Idaho, and eastern Oregon
1992	Published key and compendium to economically important group of plant-parasitic nematode genus *Hoplolaimus* (lance nematodes); emended its diagnosis and evaluated the validity of several species of the genus with a list of all valid species
1994	Discovered for the first time pea cyst nematode in western Washington, a devastating pest of peas in several countries

Potato Herbarium

By David M. Spooner and John B. Bamberg

Location U.S. Department of Agriculture, Potato Introduction Station, 4312 Highway 42, Sturgeon Bay, WI 54235–9620

Loans Short-term loans of duplicate herbarium specimens to recognized institutions and scientists

Associated libraries An extensive collection of topographic and road maps and gazetteers of Latin America and a taxonomic literature collection of the genus *Solanum* section *Petota*. These library materials are available in the office of the ARS potato taxonomist at the Department of Horticulture, University of Wisconsin-Madison.

Number of accessions 4,308 germplasm accessions of 146 species of *Solanum* section *Petota;* 14,270 herbarium sheets

Types Photographs of 273 holotype, isotype, lectotype, or syntype collections of *Solanum* section *Petota*

Curators

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Home page <http://www.ars-grin.gov/ars/MidWest/NR6/index.html>
(URL is case sensitive; follow exact capitalization.)

Background *Solanum tuberosum* (Solanaceae) is 1 species of a group of 7 cultivated and 216 additional tuber-bearing and 9 non-tuber-bearing wild relatives classified in the genus *Solanum* section *Petota*, according to the latest taxonomic review published by Hawkes in 1990. The nine non-tuber-bearing species are classified by a separate system; each species is placed in one of three sections—*Etuberosum* (Bukasov and Kameraz) A. Child, *Juglandifolium* (Rydb.) A. Child,

Figure 19. Corolla colors and shapes used in morphological classification in *Solanum* sect. *Petota*. Top left, *S. bulbocastanum* Dunal (from Mexico). Top right, *S. paucijugum* Bitter (Ecuador), showing polymorphisms within populations. Bottom left, *Solanum tuberosum* L. (cultivated and widespread). Bottom right, *S. columbianum* Dunal (Venezuela, Columbia, Ecuador).

and *Lycopersicum* (Mill.) Wettst. Classification of the non-tuber-bearing species is done on the basis of morphology (fig. 19) and chloroplast DNA. The section *Petota* of the genus *Solanum* is found from the southwestern United States to southern Chile. Seventy-two taxonomists have described 531 taxa in the section *Petota*.

The U.S. Potato Introduction Station Herbarium (PTIS) serves the National Research Support Program-6 (NRSP–6; formerly known as the Inter-Regional Potato Introduction Project, IR–1). NRSP–6 is part of the U.S. germplasm system and is the sole genebank for wild and cultivated potatoes in the United States. The genebank and herbarium are devoted entirely to wild and cultivated potatoes (*Solanum* section *Petota*). NRSP–6 is charged with the introduction, preservation, classification, evaluation, and distribution of potato germplasm worldwide. The potato research group of NRSP–6 includes John B. Bamberg (director of the genebank), Robert H. Hanneman (germplasm enhancement), and David M. Spooner (taxonomist).

NRSP–6 was created in 1948. PTIS was created in the early 1950's and has served the taxonomic research needs of various visiting researchers. In 1987, NRSP–6 incorporated a new position of collector and taxonomist to serve the genebank, and external funds from the U.S. Germplasm System were provided for the development of PTIS.

NRSP–6 has greatly benefitted from germplasm collections from many donors worldwide. These include collections of the following persons: Donovan Correll, Jack Hawkes, J. Peter Hjerting, Luis Lopez, Carlos M. Ochoa, Katsuo A. Okada and Andrea Clausen, T. Richard Tarn, and Donald Ugent. More recent collections by NRSP–6 staff and international collaborators are from Argentina, Bolivia, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Mexico, and Venezuela.

NRSP–6 maintains 4,308 accessions of 146 species of *Solanum* section *Petota*; 3,584 of these have at least 1 herbarium voucher. In total, 14,270 herbarium sheets are maintained, incorporating duplicates and sheets not represented by germplasm collections. NRSP–6 has photographs of 273 type collections of taxa of section *Petota*; long-term plans are to expand this photographic collection so that it includes all nomenclatural types. An extensive collection of topographic and road maps and gazetteers of Latin America is also maintained at PTIS.

The cabinet room at PTIS contains nine full-height steel herbarium cabinets of specimens and a table for specimen preparation and examination. Additional specimens are located in the offices of the NRSP–6 taxonomist at the Department of Horticulture, University of Wisconsin-Madison. These offices contain two full-height steel herbarium cabinets of specimens. Both locations have quarter-height, sealed, wooden cabinets to accommodate oversized herbarium sheets. The herbarium office at PTIS includes a computer, and all germplasm and herbarium holdings are entered on a DBASE IV file, freely available upon request. The workroom contains a modern stereoscopic microscope with fiber-optic ring-light illumination on a boom stand, a modern optical microscope with oil immersion objectives, and a camera adapter.

PTIS also includes all of the U.S. Department of Interior gazetteers of place names in Argentina, Bolivia, Chile, Colombia, Costa Rica, Ecuador, Guatemala, Mexico, and Venezuela and gazetteers and atlases purchased in foreign countries. It has a collection of all regional and comprehensive taxonomic treatments of *Solanum* section *Petota*. A collection of all original descriptions of 531 scientific names in *Solanum* section *Petota* and other potato systematic literature is maintained in the office of the taxonomist in Madison, WI. The map, gazetteer, and atlas coverage is expanded as field trips progress.

PTIS and all associated facilities are open year-round during normal working hours and are accessible to all interested researchers. The herbarium is staffed full-time by John Bamberg, the director of NRSP–6, and occasionally each year by David Spooner. Bamberg should be contacted for requests for the catalog of germplasm and for germplasm samples. The catalog and the samples are free. Bamberg should also be contacted regarding regulations for donations of potato germplasm, which must first pass through U.S. quarantine. Spooner should be contacted for herbarium loans. The collection welcomes specimens of *Solanum* section *Petota* as gifts for determination. While one herbarium voucher must remain at NRSP–6 to serve the daily needs of the genebank, duplicate herbarium specimens are available for short-term loan.

Identification Service

NRSP–6 collections are used in breeding and many other studies worldwide. Since 1950, NRSP–6 has distributed 150,000 samples of germplasm, but demand has increased so rapidly that orders within the past 10 years account for nearly half of this total. NRSP–6 germplasm has been used in more than 1,765 published research papers and 190 masters or doctoral theses. The majority of the authors of these works requested identifications.

Research

Solanum section *Petota* has been the subject of intensive taxonomic research by many taxonomists worldwide. There are many discrepancies among treatments regarding species boundaries, taxonomic ranks assigned to taxa, assignment of species to series, and hypotheses of hybridization. The extensive variation of taxa in *Solanum* section *Petota* makes the construction of keys difficult, and independent identifications of some problematic groups by different taxonomists frequently differ. If many taxa are of recent origin and interspecific hybridization is common, an easily used taxonomic treatment may be an elusive goal. Current research is reinvestigating alternative systematic hypotheses with combined morphological and molecular approaches.

Selected Achievements

1987–1995	Increased the number of germplasm holdings from 3,884 accessions to 4,369 accessions
1987–1995	Used morphological and molecular data to provide new insights into the systematic and evolutionary relationships of species in *Solanum* section *Petota*
1990–1994	Developed PTIS, including computerizing the collection information and increasing the size of the herbarium from 4,500 to 14,500 specimens
1990–1995	Initiated the Association of Potato Intergenebank Collaborators (APIC), a worldwide consortium of potato genebank leaders who are cooperating on common problems of potato germplasm management. These problems are related to documentation of passport and evaluation data, germplasm backup, preservation, collection, genebank technology, and research

ARS Germplasm Holdings of Grasses and Legumes

By Kevin Jensen

Location Forage and Range Research Laboratory, Utah State University, Logan, UT 84322–6300

Loans Seed requests handled by Dr. Richard Johnson, Plant Germplasm Introduction and Testing, USDA–ARS, PWA, Johnson Hall, Room 59, Washington State University, Pullman, WA 99164–6402. Small seedlots of breeding lines and clonal material are available upon request.

Associated library Plant Germplasm Introduction and Testing Office, Pullman, WA

Number of accessions 3,500

Types *Pseudoroegneria deweyi*

Curators

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Home page: none.

Content **Triticeae collection.** Tribe Triticeae is a relatively small but important group of species. It contains some of the most important cereal crops (wheat, barley, and rye) and many important forage grasses, including crested wheatgrass, tall wheatgrass, intermediate wheatgrass, bluebunch wheatgrass, Great Basin wildrye, and Russian wildrye. Depending on the taxonomic treatment used, there are approximately 325 species in the tribe, of which about 75 percent are perennials that inhabit much of the world's temperate and subarctic regions.

In addition to their value as forage and conservation grasses, the perennials in this tribe are a vast genetic reservoir for cereal improvement. The perennial habit, disease and insect resistances, and cold, drought, and salt tolerances are some characteristics of Triticeae grasses that plant breeders would like to incorporate into wheat and barley. The wheatgrasses and their perennial relatives are also valuable in basic research concerning genetics, cytogenetics, evolution, speciation, taxonomy, polyploidy, and interspecific hybridization. These grasses are valuable research tools because of their extreme morphological variation, varied ecological requirements, wide geographical distribution, diverse modes of reproduction, forms of polyploidy (they have all forms), wide range in chromosome number, large chromosomes, and unusual ability to hybridize with other species.

Since 1936, the Agricultural Research Service (ARS) has maintained a cooperative rangegrass project on breeding and cytogenetics with the Utah Agricultural Experiment Station at Logan. The project focuses on wheatgrasses and their closest relatives because of their importance on western rangeland. In 1962, Dr. Douglas Dewey began assembling perennial Triticeae germplasm from all parts of the world. The collection now contains over three-fourths of the known perennial species. The collection has been accumulated from three primary sources: (1) the USDA Regional Plant Introduction Station at Pullman, WA; (2) scientists in the United States and other countries; and (3) plant exploration by scientists of the Forage and Range Research Laboratory (FRRL) of the USDA–ARS, Utah State University. Foreign plant exploration has been a major source of germplasm (table 1). However, maintained at the FRRL is a large collection of native grass species within the tribe.

The seed portion of the collection now contains over 3,100 accessions of species representing all genera and over 500 seed lots of interspecific and intergeneric hybrids within the tribe. Within the collection, there are 400 accessions of *Agropyron* (4 species), 1,022 accessions of *Elymus* (118 species), 106 accessions of *Elytrigia* (4 species), 117 accessions of *Hordeum* (29 species), 240 accessions of *Leymus* (28 species), 31 accessions of *Pascopyrum* (1 species), 86 accessions of *Psathyrostachys* (4 species), 232 accessions of *Pseudoroegneria* (11 species), 220 accessions of *Thinopyrum* (15 species), and over 30 accessions representing *Haynaldia, Heteranthelium, Hordelymus, Secale, Taeniatherum*, and *Australopyrum*. The seed portion of the collection is maintained in four large refrigerators where the seed is stored at 30 °F and 16–20 percent relative humidity.

Native Grass Collection. Assembly of the native grass seed collection began in 1986 and now includes 956 accessions of 11 grasses of economic or potential economic importance. Taxa include *Oryzopsis hymenoides* (389 accessions), *Leymus cinereus* (193 accessions), *Pseudoroegneria spicata* (117 accessions), *Elymus elymoides* (68 accessions), *E. lanceolatus* subsp. *wawawaiensis* (50 accessions), *E. lanceolatus* subsp. *lanceolatus* (42 accessions), *Stipa robusta* (42 accessions), *S. viridula* (33 accessions), *L. triticoides* (13 accessions), *E. trachycaulus* (6 accessions), and *S. nelsonii* (3 accessions). Accessions of all taxa except *O. hymenoides* and *L. triticoides* are refrigerated. These two species are maintained at room temperature because of their characteristically high seed dormancy. Fifty-seven breeding populations, many of which represent hybrids, are also available. Table 2 lists domestic plant-collection trips from which accessions were derived.

Table 1. Foreign plant-collection expeditions (1972–1995) conducted by the Forage and Range Research Laboratory for perennial grasses and other species

Year	Country	Participants
1972	Iran-Turkey	D.R. Dewey and J.L. Schwendiman
1977	USSR	D.R. Dewey and A.P. Plummer
1979	Turkey	J.A. Hoffman and R.J. Metzger
1980	China (PRC)	D.R. Dewey, T.J. Orton, D.W. Sunderman, and R.K. Thompson
1981	Australia	D.A. Johnson
1982	USSR	K.H. Asay and M.D. Rumbaugh
1983	China (PRC)	D.R. Dewey and W. Tai
1984	Romania	M.D. Rumbaugh and N.L. Taylor
1985	Australia-New Zealand	J.G. Carman and C.F. Crane
1986	Nepal-Pakistan	D.A. Johnson
1988	USSR	K.H. Asay, D.A. Johnson, and M.D. Casler
1988	China (PRC)	R.C. Wang, Y. Cauderon, and Y.S. Dong
1989	USSR	D.R. Dewey and K.B. Jensen
1989	France	J. Jarvie and Y. Cauderon
1991	China (PRC)	D.A. Johnson and M.D. Rumbaugh
1992	USSR	K.H. Asay and D.A. Johnson
1993	China (PRC)	D.A. Johnson and K.B. Jensen
1993	Canada	T.A. Jones, B. Wark, and L. Wetter
1994	Mongolia	D.A. Johnson and D.P. Sheehy
1994	Canada	T.A. Jones and R.C. Johnson

Legume Collection. The legume living collection consists of 258 accessions of alfalfa (*Medicago* spp.), 70 accessions of birdsfoot trefoil (*Lotus* spp.), and a breeding population of kura clover (*Trifolium ambiguum*). Approximately 250 additional seed lots of *Medicago* spp. are maintained in M.D. Rumbaugh's original seed inventory. The following germplasm is maintained in the seed inventory: U 2951 and U 2954 Foxtail clover *(T. rubens)*, U 2936 Scarlet Globemallow *(Sphaeralcea coccinea)*, U 2982 Munroe Globemallow *(S. munroana)*, U 2956 Chiment sweetvetch *(Hedysarum semenowi)*, U 2953 Mongolian sweetvetch *(H. mongolicum)*, U 2923 Austrian flax *(Linum austriacum)*, U 2955 Spanish sweetvetch *(H. humile)*, U 2921 Flatpea (Perennial Sweetpea) *(Lathyrus latifolius)*, U 2922 Crown vetch *(Coronilla varia)*, and U 2962 Siberian Sainfoin *(Onobrychis sibirica)*.

Identification Service

Small quantities of seed from breeding lines and clonal materials are available at the FRRL. However, requests for large quantities of seed for raw germplasm should be made through the Plant Germplasm Introduction and Testing Office, Pullman, WA. Taxonomic identifications are made for grasses within the Triticeae tribe.

Table 2. Domestic plant-collection expeditions (1986–1995) conducted by the Forage and Range Research Laboratory for perennial grasses and other species

Year	States	Participants
1986	UT, ID, OR, WA	T.A. Jones, D.C. Nielson, and K.H. Asay
1986	NV	T.A. Jones, D.C. Nielson, and K.B. Jensen
1987	ID, OR, NV	T.A. Jones and D.C. Nielson
1987	UT, CO	T.A. Jones and K.B. Jensen
1988	NV, WA, ID	T.A. Jones and R.D.B.Whalley
1988	UT, DC	D.C. Nielson and R.D.B. Whalley
1988	UT, NM, AZ, CO	T.A. Jones, D.C. Nielson, and R.D.B. Walley
1989	UT, NV	D.C. Nielson
1989	UT, ID, OR	T.A. Jones and D.C. Nielson
1992	UT, AZ, NV	T.A. Jones
1993	ID, OR, WA	T.A. Jones
1993	UT, NV, CA	T.A. Jones
1993	UT, NM, CO	T.A. Jones
1993	UT, NM, CO, WY	T.A. Jones
1995	ID	T.A. Jones
1995	UT, CO, WY	T.A. Jones
1995	ID	T.A. Jones
1995	CO, NM, AZ	T.A. Jones

Research

The collections housed at FRRL are used to define genomic and phylogenetic relationships among component species. Many of these species, particularly grasses, are used in crosses to make interspecific and intergeneric hybrids. For the past 30 years, phylogenetic relationships within these collections have been derived using geographic distribution, morphological variation, chromosome pairing, hybrid fertility, and recently molecular techniques. Perhaps the most important use of these collections is in the development of new and improved plant materials for land revegetation and restoration, soil stabilization, pastures, and low-maintenance turf.

Recent plant releases include the following:

- Hycrest—an improved cultivar of crested wheatgrass that was developed from a hybrid between an induced tetraploid of 'Fairway' *(Agropyron cristatum)* and the natural tetraploid Standard *(A. desertorum)*.

- Bozoisky-select—an improved cultivar of Russian wildrye released in 1985. The parental germplasm for this cultivar was derived from an introduction (PI 406468) from the former Union of Soviet Socialist Republics (USSR).

- NewHy-RS Hybrid wheatgrass—a cross between quackgrass *(Elytrigia repens)* and bluebunch wheatgrass; released as a cultivar in December 1989. This new hybrid combined the vigor, productivity, salinity tolerance, and persistence of quackgrass with the drought resistance, caespitose growth habit, seed quality, and forage quality of bluebunch wheatgrass.

- Vavilov—a Siberian wheatgrass released in 1994. The parental germplasm for the cultivar Vavilov was derived from accessions originally received from the N.I. Vavilov Research Institute of Plant Industry, Stavropol Botanical Garden of the former USSR, Eskisehir Plant Breeding Station, Turkey, and from selections of the cultivar P–27.

- Douglas—the first hexaploid (2n=42) cultivar of crested wheatgrass to be released in North America. It was released in 1994. The breeding population was derived from hybrids between an accession from the former USSR (PI 406442) and three accessions from Iran (PI's 401076, 401080, and 401085) and one accession from Turkey (PI 173622).

Germplasm releases include the following:

- SL-Germplasm—derived from an amphiploid hybrid (2n=42) between the diploid (2n=14) form of bluebunch wheatgrass (PI 232132, originally collected in Utah) and thickspike wheatgrass (PI 236663, an accession from Nevada).

- ARS–2892 Munroe Globemallow—a native, xerophytic, perennial herb widely distributed in communities in which shadscale, juniper, desert shrub, and mountain brush grow. ARS–2892 is a selected ecotype originating from seed collected from naturally occurring plants growing on the Hyrum Lake Dam, Cache County, UT.

- ARS–2936 Scarlet Globemallow germplasm—a native, perennial, herbaceous species widely distributed in the Rocky Mountains and Great Plains rangelands of the western United States. Seeds of ARS–2936 were harvested from a native stand in northern Idaho in 1987.

- ARS–2678 Kura Clover germplasm—originated from 51 seed accessions obtained by D.R. Dewey and A.P. Plummer from the Stavropol Botanical Garden and originated from the Caucasus Mountain area of the former USSR.

Selected Achievements

1972–1995	Foreign and domestic plant-collection trips (see tables 1 and 2)
1984	Released cultivar Hycrest, a crested wheatgrass
1985	Released cultivar Bozoisky-select, a Russian wildrye
1989	Released cultivar NewHy, a cross between quackgrass and bluebunch wheatgrass
1990	Released germplasm of SL–1, an amphiploid hybrid between bluebunch wheatgrass and thickspike wheatgrass
1991	Released germplasm of Kura Clover
1993	Released germplasm of Scarlet Globemallow
1993	Released germplasm of Munroe Globemallow
1994	Released cultivar of Douglas, a crested wheatgrass
1994	Released cultivar of Vavilov, a Siberian crested wheatgrass
1996	Released cultivar of CD–II, a crested wheatgrass

U.S. National Arboretum Herbarium

By Frederick G. Meyer

Location U.S. National Arboretum, 3501 New York Avenue, NE, Washington, DC 20002–1958

Loans To recognized research institutions and scientists

Associated libraries 8,000 volumes; 9,000 reprints

Number of accessions 600,000

Types 2,400 (botanical and horticultural)

Curators

- Mark A. Hershkovitz, Phone: (202) 245–4550 • fax: (202) 245–4579 e-mail: <namh@ars-grin.gov>, curator and specialist in phytogeography and systematics of Caryophyllales
- Kevin Conrad, Phone: (202) 245–4513 • fax: (202) 245–4575 e-mail: <nakc@sun.ars-grin.gov>, horticulturist and collections manager
- Frederick G. Meyer (retired), specialist in herbals, flora of North America, woody cultivated plants in southeastern United States
- Thomas S. Elias (director of Arboretum), specialist in trees of North America

Home page <http://www.ars-grin.gov/ars/Beltsville/na/research/herbarum.htm> (URL is case sensitive; follow exact capitalization.)

Content The U.S. National Arboretum Herbarium is a facility for research on the systematics, nomenclature, and history of cultivated plants. Worldwide in scope, it serves as a national repository for voucher material of wild and cultivated progenitors of plants related to agriculture, including plants used for food, forage, industrial, medicinal, and drug purposes; ornamentals; weeds; and forest trees. The herbarium also contains named cultivars, hybrids, and other elite materials covering a wide diversity of cultivated plants world-

Figure 20. Compactors that house the herbarium at the U.S. National Arboretum

wide—azaleas to zoysia, beets to magnolias, lilies to economic legumes, and cotton, wheat, alfalfa, carrots, holly, crepe myrtle, African violets, and a host of others.

The herbarium contains about 600,000 specimens that are filed into compactors (fig. 20). The reference material of cultivated plants numbers between 60,000 and 70,000 specimens. The general herbarium contains an extensive reference collection of the native flora of the United States and Canada and also material from Japan, China, South America, Africa, Australia, and other areas of the world. Documented material is filed in systematic order by family (fig. 21)

One of the aims of the herbarium has always been to document germplasm materials sent to the United States by U.S. Department of Agriculture (USDA) plant explorers as a permanent legacy of the history and development of American agriculture. As to content, the present USDA herbarium dates from about 1900, based on collections of cultivated plants obtained as seeds and plants from many parts of the world by USDA plant explorers N.E. Hansen and M.A. Carleton from Russia, by the worldwide contacts of W.T. Swingle, by J.N. Rose from Mexico, by David Fairchild from many parts of the tropics, by F.N. Meyer from China, Turkestan, and the Near East, by P.H Dorsett from China and Japan, by Wilson Popenoe from Latin America, and by many others. More recent plant explorers whose collections are represented in the herbarium are D.S. Correll (Latin America), W. Koelz (Iran, Afghanistan, India), H.S. Gentry (Mexico, Middle East), J.L. Creech (Japan), T.R. Dudley (China, Peru), and F.G. Meyer (Europe, Ethiopia, Japan, southeastern United States).

Figure 21. Herbarium specimens are filed in systematic order by family

A major acquisition was the 19th century herbarium of Isaac C. Martindale, purchased in 1964 from the Philadelphia College of Pharmacy and Science. The Martindale herbarium contains about 60,000 specimens and is represented by over 700 collectors. The collection is rich in historic material of the 19th century, including types, from many parts of the world, particularly North America and Europe. U.S. collectors represented in the Martindale herbarium include C.F. and R.M. Austin, M.E. Bebb, H.N. Bolander, William M. Canby, Alvan Chapman, George Englemann, Asa Gray, E.L. Greene, Marcus E. Jones, F. Lindheimer, E.J. Palmer, S.B. Parish, C.F. Parker, C.C. Parry, Zina Pitcher, C.G. Pringle, J.H. Redfield, J. Reverchon, J.T. Rothrock, Ferdinand Rugel, and others. The collections of Rugel are important as the earliest made by a resident botanist of the southeastern United States.

Material from Europe is represented by a large number of collectors, many well known, including G. Gaudin, who wrote a flora of Switzerland in the

1830's; John Stuart Mill, famous logician, economist, and sometimes botanist; W.D.J. Koch, J.E. Planchon, A. de St. Hilaire, C.F. Hochstetter, and George Bentham. A few European collections date from the late 18th century. Also represented is a fine set of specimens collected by E.G. Post from the Middle East and another by C.F. Cheeseman from New Zealand; both collections form the basis of a flora of their respective regions.

The Carlton R. Ball willow collection, bequeathed in 1958, contains 25,000 herbarium specimens plus 700 reprints, books, notes, and bibliographic files on the genus *Salix*. Ball, a USDA agronomist for many years, was the leading authority on North American willows. The herbarium also contains material donated by various workers to document taxonomic research projects, including *Acer, Manihot, Juniperus, Pinus*, and grass hybrids. The Macay nut collection, consisting of several hundred jars of nuts, was started in the early 20th century and represents an important reference collection of nut varieties grown in the United States.

Background

The earliest herbarium in the USDA dates from 1868, when the U.S. National Herbarium of the Smithsonian Institution was transferred to the USDA. During the 1880's and 1890's, the herbarium was staffed by George Vasey, William E. Stafford, and Frederick V. Coville, who were the principal botanists at that time. On July 1, 1896, this herbarium and all of its contents were returned officially to the custody of the Smithsonian Institution under Frederick V. Coville, then chief botanist of USDA and honorary curator of the National Herbarium until his death in 1937. Between 1896 and 1934, the USDA was without an official herbarium. Nevertheless, during these 38 years various individuals within the Department were preparing herbarium specimens of nursery plants, as well as material of plant introductions sent to the United States from foreign countries under the Office of Foreign Seed and Plant Introduction, organized in 1898. (See list of collectors mentioned under Content.)

The present herbarium of the U.S. National Arboretum was formally organized in 1934 by B.Y. Morrison, then principal horticulturist, Division of Plant Introduction and Exploration, USDA. This was the first official herbarium of the USDA unrelated to the National Herbarium of 1868 and the Smithsonian Institution. For many years Morrison was chief of the Foreign Seed and Plant Introduction Office and first director of the National Arboretum. Under his leadership, the herbarium grew rapidly in the 1930's and 1940's. From its original quarters in the old agriculture building in downtown Washington, DC, the herbarium was moved to the Department's research facility at Beltsville, MD, in the late 1930's.

In 1951, the herbarium officially became part of the U.S. National Arboretum. In 1959, the herbarium was moved from Beltsville to a temporary storage area at the National Arboretum. Permanent quarters were established in the two-floor wing of the new Arboretum Administration Building in 1964. From its founding in 1934, the principal curators of the herbarium have been W. Andrew Archer to 1959, Gabriel Edwin from 1959 to 1963, Frederick G. Meyer from 1963 to 1991, and Theodore R. Dudley from 1991 to 1994.

During World War II, the herbarium had a staff of 17 botanists, many of whom were in South America collecting wild rubber *(Hevea)* and quinine *(Cinchona)* for the war effort. Botanists actively associated with the herbarium at that time included S.F. Blake, W. Andrew Archer, F.R. Fosberg, Joseph Ewan, Rogers McVaugh, F.J. Hermann, and C.H. Muller.

Identification Service

Most of the 5,000 identifications of plants requested each year are submitted by government agencies, experiment stations, educational institutions, botanic gardens, embassies, garden clubs, farmers, and the general public. Federal Government and other researchers submit identification requests for ongoing research projects. Normally material is submitted as dried, pressed specimens or as fresh material by mail or by hand delivery to the herbarium technician or head curator. The curator makes the identification and sends the results to the requesting person or agency. Identification may take minutes, but often the material must be compared with other material in the herbarium to ensure accuracy. Requests for identification should be submitted to: Curator of the Herbarium, U.S. National Arboretum, U.S. Department of Agriculture, 3501 New York Ave., NE, Washington, DC 20002–1958.

Research

Research at the U.S. National Arboretum Herbarium centers on the nomenclature and taxonomy of cultivated plants. Research topics normally apply to specific plant groups, some of which are of economic importance to humans. From 1940 to 1965, a major project was the multiauthored *Contributions Toward a Flora of Nevada*, issued in 50 parts, under the general direction of W. Andrew Archer. Other research projects have covered *Betula, Coffea, Fothergilla, Hamamelis, Ilex, Koelreuteria, Magnolia, Malus, Rhododendron* (subgenus *Azalea*), and *Viburnum*.

Selected Achievements

1941	Issued first volume of geographical guide to floras of the world
1942	Published monograph on Central American oak trees of the genus *Quercus*
1953	Published descriptive list of Glenn Dale azalea cultivars, a new class of hardy azaleas
1961	Issued first descriptive list of bamboos cultivated in the United States
1961	Issued second volume of geographical guide to floras of the world
1962	Monographed the soybean genus *Glycine*
1964	Acquired Isaac C. Martindale herbarium
1965	Terminated series on contributions toward flora of Nevada
1965	Published first flora of Japan in English
1976	Monographed the genus *Koelreuteria*
1976	Rediscovered *Betula uber*, a species from Virginia thought to be extinct
1983	Published comprehensive account on the flora of Staten Island, Tierra del Fuego, Argentina
1986	Completed manuscript on the great herbal of Leonhart Fuchs (1501–66)
1994	Published catalog of cultivated woody plants of the southeastern United States

U.S. National Seed Herbarium

By Joseph H. Kirkbride, Jr., and Charles R. Gunn

Location U.S. Department of Agriculture, Agricultural Research Service, Systematic Botany and Mycology Laboratory, BARC-West, 10300 Baltimore Boulevard, Building 011A, Room 324, Beltsville, MD 20705–2350

Loans None

Associated libraries 5,000 volumes

Number of accessions 120,000 seed and fruit samples; 390 families; 13,000 genera; 27,000 species

Types None

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Home page <http://nt.ars-grin.gov/sbmlweb/seedcollection/seedframe.htm>

Background

The U.S. National Seed Herbarium is the world's largest taxonomic seed collection. Its director provides research material and rapid identifications of isolated seeds and fruits of economically important plants. Since its inception, the U.S. National Seed Herbarium has been closely associated with the USDA worldwide Plant Introduction (PI) Program. Viable seed lots of important crop species and their relatives are stored in the U.S. Department of Agriculture (USDA), Agricultural Research Service (ARS), National Plant Germplasm System (NPGS). This program has introduced more than 590,000 accessions, most of them seeds.

The first recorded PI for which a seed sample was kept was a cultivar of cabbage received from Russia in February 1898 (PI 3). PI samples were kept in a temporary fashion until 1908, when Homer C. Skeels, Office of Taxonomic and Range Investigations, U.S. Bureau of Plant Industry, established the seed herbarium. He continued to curate and expand it until his death in 1934.

Figure 22. Scientist moving the open-face compactors in which the U.S. National Seed Herbarium is stored

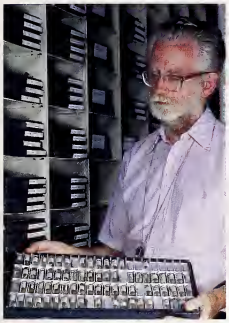

Figure 23. Scientist examining seed samples stored in glass vials

Subsequently, Paul Russell took over management of the seed herbarium and enlarged it into a major taxonomic collection. Following his retirement in 1960, he continued as curator until his death in 1964. Between 1960 and 1964, Eugene Griffth was responsible for managing the herbarium and adding new accessions. Charles R. Gunn, the first professionally trained seed taxonomist in charge of the herbarium, was director from 1965 until his retirement in 1992. Joseph H. Kirkbride, Jr., was appointed director following Gunn's retirement.

Prior to 1965, the primary activities associated with the U.S. National Seed Herbarium were identifications of specimens and accessioning of samples. In 1965, the emphasis was expanded to include research and documentation. With this change the seed herbarium was converted from a museum-type collection into a research collection. The container series for different sizes of seeds and fruits were reduced from 6 to 2, all samples were checked, and the number of herbarium cases increased to 34. Procedures for documenting the seed and fruit samples were established with the advent of a card control system, which was later computerized. Many samples are vouchered by herbarium specimens deposited in the U.S. National Herbarium (of the Smithsonian Institution) and the U.S. National Arboretum Herbarium (of ARS). In 1992, the collection was transferred to an open-faced compactor unit of five carriages with 1,512 pigeonholes (figs. 22 and 23).

The Systematic Botany and Mycology Laboratory (SBML) is also responsible for vascular plant nomenclature for ARS and the USDA–ARS, Germplasm Resources Information Network (GRIN), as well as for the identification of vascular plants, especially crops from the PI program and weeds. John H. Wiersema handles nomenclature and studies the systematics of water lilies, Cabombaceae and Nymphaeaceae. In addition to his seed and fruit identifications, Joseph H. Kirkbride, Jr., identifies legume plants and works on the systematics of birdsfoot trefoil (*Lotus*, Fabaceae), cucumbers and melons (*Cucumis*, Cucurbitaceae), and neotropical Rubiaceae.

Identification Service

Many of the 500 identifications made each year are derived from PI accessions. Identifications are also made for inspectors of the Animal and Plant Health Inspection Service, ARS scientists, the National Seed Testing Standardization Laboratory, the Natural Resources Conservation Service, the Smithsonian Institution, U.S. Customs and other law-enforcement agencies, state seed laboratories, and foreign departments of agriculture. The public often asks for identification of poisonous seeds and fruits.

Databases

GRIN is the centralized database for more than 450,000 germplasm accessions still active in NPGS. A broad range of data is stored for each accession: passport, taxonomic, descriptor, observation, evaluation, and inventory data. The taxonomic data provide the framework of the database and are the principal reason for accessing it. Included in the taxonomic data are about 13,000 accepted and 4,000 synonymous generic names covering all accepted vascular plant genera, 33,000 accepted and 17,000 synonymous specific and infraspecific names, 8,500 common names, 58,000 distribution records, and 105,000 taxonomic reference citations. Approximately 9,150 accepted specific

and infraspecific names are attached to viable germplasm accessions. The remainder of the accepted specific and infraspecific names are included because they are economically important germplasm relatives, weeds, timbers, drug sources, erosion controllers, and so forth. GRIN can be accessed through the Internet via the World Wide Web at <http://www.ars-grin.gov/>, through Gopher at <gopher.ars-grin.gov>, through TELNET, or through FTP at <sun.ars-grin.gov>.

Descriptive data are now kept in Description Language for Taxonomy (DELTA) format, the internationally recognized standard for exchange of descriptive data, using the DELTA software system of Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia. Morphological and macrodistributional DELTA data sets are available for all genera of Fabaceae for seed and fruit characters and for *Cucumis* and *Cucumella* for a broad range of vegetative and reproductive characters. The data sets may be requested from the director.

Research

The first complete study of the seeds and fruits of legumes (Fabaceae), including 149 genera of subfamily Caesalpinioideae, 58 genera of subfamily Mimosoideae, and 455 genera of subfamily Faboideae, was recently completed. The results will be available in printed form and as a computer database with video images for interactive identification of specimens or data querying. This will continue a tradition, started in 1973 with the seeds and fruits of Papaveraceae and Fumariaceae, of presenting results in formats for interactive use on computers.

A revision is under way of the checklist of vascular plants important to agriculture. A number of plants not included previously are being added, resulting in a significant expansion of the list. In addition, an in-depth nomenclatural study of the economically important members of the rose family (Rosaceae) is planned. This will include many important northern temperate fruit, nut, and ornamental plants such as almonds, apples, blackberries, hawthorns, peaches, roses, and strawberries. A biosystematic monograph of the trefoils (Fabaceae: *Lotus*) is also being prepared. This genus of approximately 175 species includes agricultural species, such as *L. corniculatus*, and ornamental species.

Selected Achievements

1968	Revised the ryegrasses (Poaceae: *Lolium*)
1969	Identified deadly poisonous *Abrus precatorius* seeds in jewelry, causing U.S. Food and Drug Administration to stop importation, interstate movement, and sale of these seeds
1973	Identified seeds using an interactive computer
1975	Made service identifications of papaveraceous seeds and fruits using an interactive computer
1977	Circumscribed alfalfa *(Medicago sativa)* subspecies by legume-flower characters
1977	Published checklist of approximately 3,000 vascular plants important to agriculture
1979	Revised vetches of North America (Fabaceae: *Vicia*)
1980	Described seeds and fruits of Papaveraceae and Fumariaceae
1980	Published vascular flora of Washington County, MI
1983	Published nomenclator of all legume (Fabaceae) genera
1984	Described seeds and fruits of subfamily Mimosoideae (Fabaceae)
1986	Published revised checklist of about 3,300 vascular plants important to agriculture
1987	Revised Australian Paniceae (Poaceae)
1987	Monographed the neotropical water lilies (Nymphaceae: *Nymphaea* subgenus *Hydrocallis*)
1988	Described disseminules of Federal noxious weeds
1989	Revised New World genera of Paniceae (Poaceae)
1990	Published nomenclator of legume (Fabaceae) species important to agriculture
1991	Described seeds and fruits of subfamily Caesalpinioideae (Fabaceae)
1991	Revised Old World genera of Paniceae (Poaceae)
1992	Published families and genera of seed plants recognized by ARS
1993	Monographed cucumbers and melons (Cucurbitaceae: *Cucumis*)
1994	Revised the genus *Cucumella* (Cucurbitaceae)